Cattle Gains and Plant Responses From Spring Grazing On Crested Wheatgrass In Northern New Mexico

F—502655

Production Research Report No. 74
United States Department of Agriculture, Forest Service
August 1963

ACKNOWLEDGMENT

The studies reported here were conducted in cooperation with the New Mexico Agricultural Experiment Station, the Carson National Forest, and several individuals. Especially appreciated is the assistance given by the Royal brothers, Antonito, Colo., who furnished cattle for grazing on the No Agua site; several livestock producers living in the vicinity of Cebolla Mesa who furnished cattle for the studies on the Cebolla Mesa site; and Professor H. B. Pingrey (deceased), Agricultural Economist at the New Mexico Agricultural Experiment Station, who assisted with many phases of the studies.

CONTENTS

Cattle Gains and Plant Responses From Spring Grazing On Crested Wheatgrass In Northern New Mexico

By H. W. Springfield, *Rocky Mountain Forest and Range Experiment Station*

INTRODUCTION

Crested wheatgrass [1] is the most commonly used grass for seeding spring-fall ranges in northern New Mexico. Extensive seedings have proved its adaptability to a wide range of conditions. Seeded areas have a particular value in the management of northern New Mexico ranges. They help bridge the gap between winter and summer ranges. Forage supplies in the northern part of the State often are critically short during May and June before the advent of the usual summer rains. Crested wheatgrass is particularly valuable because it ordinarily makes maximum growth during these months. By supplying much-needed spring forage, crested wheatgrass stands carry a large part of the grazing load that formerly was put on the higher elevation native ranges every spring, especially in north-central New Mexico. As a result of lessened grazing, especially too early grazing, these native ranges—which have high value for summer grazing and as watersheds—are being given an opportunity to improve naturally.

Ranchers and range managers alike are interested in knowing how to manage crested wheatgrass. Their goal is to obtain maximum livestock production and still maintain adequate stands. Some of the principles and practices developed in other parts of the West may not apply to northern New Mexico, for environmental conditions here are considerably different. Moreover, this area is near the southern limit of the range of crested wheatgrass.

Results of experiments conducted in northern New Mexico from 1952 to 1959 have provided useful information and furnished guides for managing crested wheatgrass for spring grazing by cattle. The general objective of these experiments was to determine the optimum intensity of grazing crested wheatgrass stands by cattle during the critical period from early May to mid-June. Specific objectives were (1) to compare gains of cattle grazed at different intensities on crested wheatgrass for a 30- to 40-day period in the spring, (2) to compare cattle gains on crested wheatgrass with those on native range, and (3) to determine the effects of different intensities of spring grazing on crested wheatgrass production and cover conditions.

[1] Common and botanical names of plants are listed on page 44.

REVIEW OF LITERATURE

The only available research results that relate to grazing crested wheatgrass in New Mexico are from fall grazing trials on Glorieta Mesa, near Pecos (Reynolds and Springfield 1953).[2] Three years of grazing trials showed that daily gains of yearling cattle averaged 1.1 pounds under the heaviest grazing compared with 2.0 pounds under moderate grazing for a month-long fall season. Wide fluctuations in production from year to year were found at the Glorieta Mesa site. Conclusions based on these trials were to remove not more than 45 to 55 percent of the current year's growth during the early fall. Higher degrees of utilization at this time resulted in loss of plant vigor and decline in herbage production. Crested wheatgrass proved to be poorly adapted on this site, however, since nearly all plants inside protected plots as well as in the pastures died within a few years because of a combination of drought and gopher damage.

Investigations in other regions have furnished information of value in interpreting results of the New Mexico experiments. One of the more comprehensive experiments on spring grazing of crested wheatgrass was at Benmore, Utah (Frischknecht et al. 1953). Results of the first 4 years of study showed that adult cattle gained 3.03, 2.90, and 2.21 pounds a day under light (50 percent herbage removal), medium (65 percent), and heavy grazing (80 percent), respectively. Intensity of grazing likewise influenced daily calf gains, which were significantly less under heavy grazing. Heavy grazing produced slightly more gain per acre than medium grazing during the first 2 years, but this was reversed in the next 2 years. Stocking rates for 4 years averaged 3.1 acres per cow-month for the light intensity, 2.4 acres for the medium, and 1.8 acres for the heavy. Light grazing allowed considerable old growth to accumulate on grass bunches, but utilization was more uniform and old growth did not accumulate under the medium and heavy grazing. Density of crested wheatgrass increased 54 percent on the average, and no difference due to grazing treatment was detected. Fewer young wheatgrass plants, however, became established under heavy grazing.

In an 11-year study near Miles City, Mont., crested wheatgrass produced rapid gains in feeder calves grazed in the spring and early summer (Woolfolk 1951). A conclusion of the study was that stocking under eastern Montana conditions should be slightly less than one animal-unit-month per acre.

General recommendations from a review of 20 years' information in the Intermountain Region are to leave 30 to 40 percent of the crested wheatgrass herbage on level areas and 40 to 60 percent on sloping lands to maintain vigor and productivity of the seeded stand (Plummer et al. 1955). Presumably these standards apply to both spring and fall grazing.

In studies conducted at the Great Divide Experimental Range near Craig, Colo., yearling steers gained an average of 30.6 pounds per acre on crested wheatgrass during a 4-month spring and summer season (Hervey 1958).

Grazing experiments at Manitou Experimental Forest near Woodland Park, Colo., showed that herbage production of crested wheat-

[2] Names and dates in parentheses refer to Literature Cited, p. 45.

grass fluctuated widely from year to year in response to varying precipitation (Johnson 1959). In the drought year of 1951, the yield was only 20 percent of the 1948 yield. Utilization to 2-, 4-, and 6-inch stubble heights during the spring-summer-fall season had no great effect on herbage production during 9 years of study. These stubble heights represented an average utilization of 67, 46, and 31 percent by weight. Heavy grazing resulted in shorter leaf lengths at the start of spring grazing, which indicates a decrease in plant vigor or delay in development. Johnson concluded that grazing to a 2-inch stubble did not injure crested wheatgrass, though very little litter was left for maintaining good soil conditions.

Several experiments have shown that heavy grazing gives maximum cattle gain per acre and greatest profits for a few years. Then, if the heavy grazing is continued, the grass stand is damaged, herbage production is reduced, and beef production and profits decline. Light grazing, on the other hand, usually gives maximum gain per animal but is not economically feasible. The proper intensity of grazing is difficult to determine, but most likely lies somewhere between maximum gain per animal and maximum return per acre (Stoddart and Smith 1955).

Cook et al. (1958) conducted clipping studies in northern Utah for 5 years to determine the effects of season, intensity, and frequency of herbage removal upon crested wheatgrass. Generally, yield from plants clipped at 3 inches was greater than from plants clipped at 1 inch. Increasing the frequency of clipping decrease herbage yield, but the extent was dependent on date and number of clippings. Combinations of early and close clipping usually resulted in high-quality herbage, but quantity declined rapidly each year the plants were harvested.

Several studies of reestablishment of woody plants in crested wheatgrass stands have been made. After 4 years of experimental grazing at Benmore, Utah, young plants of sagebrush and rabbitbrush were commonly found growing in the dead centers or near the edges of weakened crested wheatgrass plants or on spots where there was less than a full stand of crested wheatgrass (Frischknecht et al. 1953). Observations elsewhere in the Intermountain Region indicated that survival of sagebrush seedlings is usually much less in a full, vigorous stand of seeded grass than where the stand either is thin at the outset (Blaisdell 1949), or is weakened by too heavy use (Frischknecht and Plummer 1955).

METHODS OF STUDY

Description of the Experiment and Experimental Sites

Pastures used in the experiment were at two sites representative of range seeded to crested wheatgrass in northern New Mexico (fig. 1), the Cebolla Mesa site and the No Agua site.

The Cebolla Mesa site is 22 miles north of Taos, N. Mex., at an elevation of 7,500 feet. Annual precipitation averages 13 inches. The native vegetation consists chiefly of big sagebrush, scattered pinyon and one-seed juniper, and a sparse understory of blue grama and western wheatgrass. An area of approximately 500 acres was plowed and seeded to crested wheatgrass in the summer of 1947. The area was

Figure 1.—Locations of experimental sites in northern New Mexico.

not grazed until May 1949 when 48 head of cattle grazed for 1 week. Early in 1950, two 42-acre pastures and one 50-acre pasture were fenced within the seeded area. Topography is gently sloping. The north one-third of each of the three pastures faces north or northwest, with slopes of 2 to 5 percent. The middle third is almost level, while the south third of each pasture faces south or southwest, with slopes of 2 to 8 percent. Soils are of mixed origin and relatively shallow. The topsoil is a silt loam that varies from 2 to 6 inches deep. It is underlain by a silty clay layer that extends to a depth of 12 to 18 inches, where a nearly impermeable caliche is found.

In 1950, the largest pasture was grazed by 22 head of cattle from May 2–15, and by 27 head from May 16–30. The other two pastures were grazed by 46 head from May 31 to July 5 and by 26 head from July 6–17, 1950. Estimated utilization of the three pastures in 1950 averaged about 50 percent. The pastures were not grazed in 1951. Spring grazing at different intensities was begun in 1952 and continued through 1958. The objective was to graze one pasture at an average of 75 percent utilization by weight, another at 50 percent, and a third at 25 percent. These percentages were based on the weight of forage produced by the end of the grazing period and did not include regrowth on all pastures after the cattle were removed. Grazing intensities were assigned at random to pastures. When grazing trials started in 1952, the crested wheatgrass stand was less dense and less productive, and big sagebrush plants not killed by plowing were more numerous on the pasture assigned the heaviest grazing.

Since the only available native sagebrush range adjacent to the seeded stand was in such poor condition that practically no grass was

produced under the sagebrush, no direct comparison could be made between unseeded sagebrush and seeded range. On Cebolla Mesa, however, cattle graze mostly in the adjacent woodland type. Therefore, an area of mixed pinyon-juniper woodland and big sagebrush, 498 acres in size about 2 miles from the experimental pastures and typical of spring range in the vicinity, was fenced in 1953 to give some measure of cattle gains on native range. Blue grama was the principal forage species. Less common were plants of mountain muhly, Junegrass, Kentucky bluegrass, and silvertop sedge. Air-dry herbage yields of the forage species varied from 11 pounds per acre in a dry year to 90 pounds in a wet year. This low production of forage was due to the dense tree and shrub overstory, coupled with poor range conditions that resulted from a long history of grazing use. Utilization ranged from 2 to 30 percent for blue grama, 5 to 30 percent for sedge, 10 to 25 percent for bluegrass, and 5 to 40 percent for mountain muhly; the percentages depended on the site and year of measurement.

The No Agua site is 4 miles north of Tres Piedras, N. Mex., at an elevation of 8,300 feet. Annual precipitation averages 15 inches. Native vegetation consists of Greenes and Vasey rabbitbrush, low sagebrush, snakeweed, pingue, blue grama, western wheatgrass, and widely scattered ponderosa pine trees. A 2,200-acre area was plowed and seeded to crested wheatgrass in 1949. The area was first grazed lightly by cattle in May and early June in 1952 and 1953. An area of about 30 acres was selected for study within the larger area. Topography of the small area is sloping. The north half has a northeast exposure with slopes ranging from 4 to 10 percent. The south half faces east and southeast with slopes of 3 to 6 percent. Soils are shallow and moderately rocky with a few remnants of basalt. The topsoil is a loam that varies from 2 to 6 inches deep above a layer of silty clay loam 10 to 18 inches deep. A hard layer of calcareous clay is found at depths of 12 to 24 inches.

Three pastures, 10 to 11 acres in size, fenced in 1954 after the grass had been utilized at an average of 54 percent in May. One pasture was selected at random for the heaviest grazing (75 percent utilization by weight), one pasture for medium grazing (50 percent use), and one for the lightest grazing (25 percent use). As on Cebolla Mesa, these percentages did not include the regrowth produced after the cattle were moved from the area.

A native ponderosa pine range adjoining the seeded area at No Agua was used to compare data on yearling cattle gains during 1 year of the study. Vegetation measurements were not taken on the native range area, which was a large National Forest grazing allotment with blue grama, western wheatgrass, Arizona fescue, mountain muhly, and silvertop sedge as the principal forage species growing as understory to ponderosa pine and Gambel oak.

Cattle exclosures, approximately 1 acre in size, were located either within or adjacent to each of the three pastures at both Cebolla Mesa and No Agua to provide comparisons of yield and ground-cover changes under the grazing intensities with those on ungrazed crested wheatgrass.

Herbage-yield and other data were also obtained at Collins Ranch, 40 miles north of Cuba, N. Mex., where grazing experiments were conducted from 1954 to 1957. This site is at an elevation of 7,400 feet,

and annual precipitation averages 16.5 inches. Native vegetation consists of ponderosa pine, pinyon, Rocky Mountain juniper, big and silver sagebrush, Douglas and rubber rabbitbrush, blue grama, and western wheatgrass. The site was seeded to crested wheatgrass in 1950. Samples of crested wheatgrass collected from this site in May 1954 were used in digestibility studies (Watkins 1955).

Additional data were collected from eight areas seeded to crested wheatgrass on the Carson and Santa Fe National Forests. Movable cages were installed and production was recorded on these seedings in 1956 and 1957.

Measurement of Plants and Grazing

Yields of the crested wheatgrass herbage were obtained by clipping random samples at the end of each spring grazing season, which corresponded to the end of the spring growing season in most years. Herbage protected from grazing by a movable wire cage was clipped from circular plots containing 9.6 square feet. Samples were weighed green in the field, saved, and reweighed when air-dry. Current year's growth of all plants with crowns within each plot was clipped to ground level. Cages were moved to new randomly located plots at the beginning of each grazing season. The locations for any one cage were confined within an area approximately 100 feet in diameter to reduce sampling variability. The objective was to measure yield in any pasture within 15 percent of the mean with a 1-in-20 chance of greater variation. This objective was not always met at Cebolla Mesa until 1955, when the number of cages was increased.

At Cebolla Mesa each pasture was divided into three strata, nearly equal in size, based on distance from water. For the years 1952 through 1954, 10 plots were located in each stratum, for a total of 30 plots per pasture; then, from 1955 through 1959, 15 plots were located in each stratum, for a total of 45 per pasture. At No Agua, the pastures were divided into two strata on the basis of aspect and location of water. Twelve plots were located at random in each stratum for a total of 24 per pasture.

Utilization at the end of grazing was determined by the difference method (Fuelleman and Burlison 1939). This method is based on the assumption that the difference in yield between a protected and nearby grazed area is equal to the herbage consumed. Four grazed samples, each consisting of herbage left on a 9.6-square-foot circular plot, were taken at every cage location at the end of the grazing season. For convenience, these samples were taken 30 feet in each cardinal direction from the cage. Herbage weights were estimated on all four plots; then herbage was clipped and weighed from one. Estimates were adjusted by the regression relationship between estimated and actual weights from the clipped plots. This modified double-sampling technique (Wilm et al. 1944) materially improved the efficiency of field operations. Only the current year's growth was included in the sample weights. Utilization was expressed as percent by weight on an air-dry basis.

Because growing conditions varied widely from year to year (as discussed later), the utilization objectives of 75, 50, and 25 percent were not always met (table 1). Average utilization for the 7 years of spring grazing at Cebolla Mesa was 69 percent for the heaviest, 55 percent for the medium, and 41 percent for the lightest intensity. For the 4 years

685-283 O - 63 - 2

TABLE 1a.—*Periods of grazing, numbers of cows and calves, animal-unit-months of grazing, and utilization obtained on experimental pastures at Cebolla Mesa, 1952–58*

Year and pasture	Grazing period			Cows [1]	Calves [1]	Animal units [2]	Animal unit months [3]	Acres per animal unit month	Utilization obtained
	Start	End	Days						
			No.	*No.*	*No.*	*No.*	*No.*	*No.*	*Percent*
1952:									
Heaviest	May 12	June 11	30	8	8	13. 04	13. 04	3. 21	81
Medium				7	5	9. 91	9. 91	4. 24	58
Lightest				8	6	11. 54	11. 54	4. 38	57
1953:									
Heaviest	May 2	June 2	31	7	7	8. 75	9. 04	4. 54	62
Medium				6	6	7. 50	7. 75	5. 29	44
Lightest				5	5	6. 25	6. 46	7. 68	28
Native				8	8	10. 00	10. 33	48. 21	----------
1954:									
Heaviest	Apr. 30	June 2	33	7	7	8. 75	9. 62	4. 26	49
Medium				6	6	7. 50	8. 25	4. 97	42
Lightest				5	5	6. 25	6. 88	7. 21	20
Native				7	7	8. 75	9. 62	51. 77	----------
1955:									
Heaviest	May 4	June 15	42	9	9	11. 25	15. 75	2. 60	78
Medium				6	6	7. 50	10. 50	3. 90	63
Lightest				4	4	5. 00	7. 00	7. 09	44
Native	May 4	June 7	34	6	6	7. 50	8. 50	58. 59	----------
1956:									
Heaviest	May 4	June 1	28	7	7	8. 75	8. 17	5. 02	72
Medium				5	5	6. 25	5. 83	7. 03	56
Lightest				3	3	3. 75	3. 50	14. 17	46
Native				4	4	5. 00	4. 67	106. 64	----------

See footnotes at end of table.

TABLE 1a.—*Periods of grazing, numbers of cows and calves, animal-unit-months of grazing, and utilization obtained on experimental pastures at Cebolla Mesa, 1952–58—Continued*

Year and pasture	Grazing period			Cows [1]	Calves [1]	Animal units [2]	Animal unit months [3]	Acres per animal unit month	Utilization obtained
	Start	End	Days						
			No.	*No.*	*No.*	*No.*	*No.*	*No.*	*Percent*
1957:									
Heaviest	May 8	June 6	29	9	9	11. 25	10. 88	3. 77	72
Medium				6	6	7. 50	7. 25	5. 66	68
Lightest				4	4	5. 00	4. 83	10. 27	44
Native				6	6	7. 50	7. 25	68. 69	----------
1958:									
Heaviest	May 6	June 19	44	10	10	12. 50	18. 33	2. 24	66
Medium				7	7	8. 75	12. 83	3. 20	57
Lightest				5	5	6. 25	9. 17	5. 41	45

[1] Cows 3 to 7 years old, calves 7 to 60 days old. In 1952 dry cows and yearling heifers used as test animals.

[2] Conversion factors: Dry cow (600–900 lbs.) 0.88 animal unit. Cow (600–900 lbs.) with suckling calf 1.25 animal unit.

[3] $\text{Animal unit months} = \frac{\text{Animal unit} \times \text{No. of days}}{30}$

TABLE 1b.—*Periods of grazing, number of yearlings, animal-unit-months of grazing, and utilization obtained on the experimental pastures at No Agua, 1955–58*

Year and pasture	Grazing period			Yearlings [1]	Animal units [2]	Animal unit months [3]	Acres per animal unit month	Utilization obtained
	Start	End	Days					
			No.	*No.*	*No.*	*No.*	*No.*	*Percent*
1955:								
Heaviest	May 10	June 13	34	8	6.00	6.80	1.66	83
Medium				6	4.50	5.10	1.99	58
Lightest				4	3.00	3.40	3.30	31
1956:								
Heaviest	May 8	June 2	25	6	4.50	3.75	3.02	77
Medium				4	3.00	2.50	4.06	76
Lightest				3	2.25	1.88	5.97	38
1957:								
Heaviest	May 10	May 31	21	6	4.50	3.15	3.59	70
Medium	May 10	June 7	28	4	3.00	2.80	3.62	52
Lightest	May 10	June 7	28	3	2.25	2.10	5.35	42
1958:								
Heaviest	May 7	June 12	36	5	3.75	4.50	2.51	79
Medium				4	3.00	3.60	2.82	38
Lightest				3	2.25	2.70	4.16	27

[1] Yearlings 12 to 14 months old.

[2] Conversion factor: Yearling steers and heifers (400–600 lbs.) 0.75 animal units.

[3] Animal unit months $= \frac{\text{Animal unit} \times \text{No. of days}}{30}$

of grazing at No Agua, the averages were 77, 56, and 34 percent, respectively.

When the mid-June yield of ungrazed plants was used as a standard in calculating percent utilization, percentages were lower than if utilization had been calculated from the yield of grazed plants. This results from assuming that growth rate is the same for ungrazed as for grazed plants when, in fact, total yield is reduced by intermittent forage removal during the grazing season (Cook and Stoddart 1953). Percentages are higher, however, than they would be if calculations were based on fall yields of ungrazed plants.

Culm heights of ungrazed crested wheatgrass plants were measured at the end of grazing each year 1954 through 1959 at Cebolla Mesa and 1955 through 1959 at No Agua. All plants with seed heads within each caged plot were measured. The measurement was made from the soil to the tip of the tallest culm as suggested by Heady (1957). Basal diameters of approximately 150 individual crested wheatgrass plants were measured at each site in 1955, and of more than 2,000 plants at Cebolla Mesa and 1,000 plants at No Agua in 1957 and 1959.

Changes in ground cover were studied by measuring permanent loop transects (Parker 1951). The objective was to measure crested wheatgrass cover within 20 percent of the mean at the 0.05 probability level. At Cebolla Mesa, six transects were randomly located on each pasture in 1952. Analysis of the 1952 data indicated a need for more transects; therefore, another 12 transects were added in each pasture in 1955. In 1955, three transects also were located within each of the 1-acre exclosures adjacent to the pastures. At No Agua, 12 permanent loop transects were randomly located in 1955 on each pasture and four transects inside each exclosure. All transects were remeasured in 1957 and 1959.

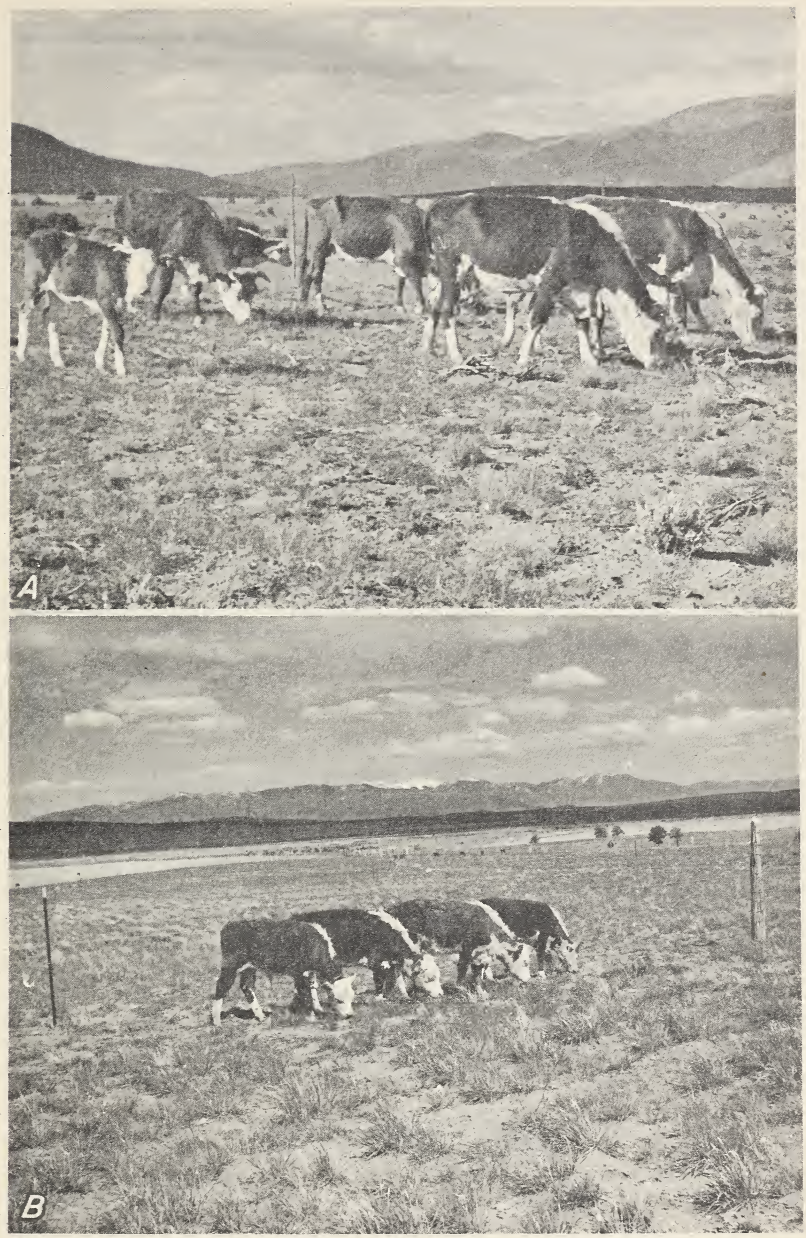
Random samples of crested wheatgrass herbage were collected on the experimental pastures in May of 1955 and 1956 for chemical analyses. The chemical determinations were made by W. E. Watkins, animal nutritionist at the New Mexico Agricultural Experiment Station.

Changes in big sagebrush at Cebolla Mesa were studied on 30 permanent milacre plots in each pasture in 1954 and again in 1958. Measurements included crown-cover determinations and counts of mature and young sagebrush plants with stems originating in each plot. Plants less than 12 inches tall and with a crown diameter of less than 8 inches were classed as young plants. In 1958, counts were also made on 100 additional plots in each pasture to give a more adequate sample.

Stocking and Cattle Gains

Hereford cattle, usually low in grade and often of mixed breeding, were used as test animals on Cebolla Mesa (fig. 2, *A*). Cows with suckling calves were grazed because yearlings were not available from local operators. The cows were extremely thin at the beginning of each spring grazing period because of the prevailing practice of letting the cattle shift for themselves during the winter with little or no supplements.

Hereford yearlings were used as test animals at No Agua. They were high in grade, uniform in size, and in moderately good flesh as a result of being fed hay during the winter (fig. 2, *B*).



F—502659, 502657

Figure 2.—Class and grade of cattle used as test animals: *A*, Cows and calves of mixed breeding and low grade on pasture given heaviest grazing at Cebolla Mesa in 1955; *B*, yearlings, uniform grade and size and of good breeding, on pasture given lightest grazing at No Agua in 1955.

Cattle were allotted to the Cebolla Mesa pastures on the basis of weight and ownership. Each pasture received approximately the same proportionate share of cattle of each owner; also, average entering weights were approximately equal. At No Agua, where cattle of one owner were used, yearlings were allotted to pastures to balance weight and sex as nearly as possible.

Animals were weighed individually at the beginning and end of each spring grazing season after being held overnight in a corral without feed or water to minimize differences in fill among animals.

Stocking rates were predicted in advance of the spring grazing each year. These predictions were made in part from samples of herbage clipped from the pastures in late April, but primarily from records of overwinter precipitation. A regression of herbage yields on November-through-March precipitation was developed from 1949–52 data from several sites similar to and including the Cebolla Mesa site. Later, an improved regression relationship based on October-through-March precipitation for the two previous years was used for predicting stocking rates at the two sites.

Stocking rates were varied from year to year because of large fluctuations in precipitation and forage production. In an attempt to achieve the prescribed utilization, both the number of animals per pasture and the period of grazing were adjusted yearly (table 1).

Weather Conditions

Precipitation during the years of study was below average, according to records at Cerro, the official U.S. Weather Bureau station 10 miles north of Cebolla Mesa, and at Tres Piedras, the station 4 miles south of No Agua (table 2). Annual precipitation at Cerro during the 9-year period 1951–59 averaged 11.58 inches, 1.59 inches below the 33-year average. Dry conditions also prevailed at Tres Piedras, where precipitation during the 6-year period 1954–59 averaged 1.64 inches below the 41-year average of 14.78 inches. Annual precipitation for the first 5 years of experimental grazing at Cebolla Mesa was less than in any other 5-year period in 33 years, except for the period 1944–49. Similarly, annual precipitation at Tres Piedras during the first 3 years of grazing at No Agua averaged less than in any other 3-year period in 41 years of record, except for the 3 years, 1952–55.

U.S. Weather Bureau records show that the precipitation in 1956 at Cerro and at Tres Piedras was the lowest on record. By contrast, the year 1957 was unusually wet. The 18.33 inches received at Cerro was the third highest annual amount in 33 years, while the 18.70 inches at Tres Piedras was the seventh highest amount on record. Thus, an extremely wet year as well as the driest year was included in the period of study.

October-through-May precipitation, which was found to be closely correlated with crested wheatgrass growth, also was generally below average during the years of study (table 2). At Cerro, precipitation during this period was below the long-term average in 6 of 9 years. At Tres Piedras, October-through-May precipitation was less than the long-term average in 5 of 6 years. October-May precipitation preceding the 1956 grazing period totaled only 3.31 inches at Cerro, less than in any year since 1943 and the third lowest amount in 33 years of record. At Tres Piedras, the total was only 3.23 inches, which was next to the lowest amount recorded in 41 years.

TABLE 2.—*Annual and October-through-May precipitation at U.S. Weather Bureau stations near the experimental sites*

Year	Precipitation	
	Annual	October through May
CEBOLLA MESA (Weather Bureau station at Cerro, 10 miles north of site)		
	Inches	*Inches*
1951	10. 00	5. 36
1952	11. 70	6. 56
1953	12. 19	5. 38
1954	11. 24	8. 65
1955	10. 62	6. 18
1956	7. 26	3. 31
1957	18. 33	7. 39
1958	9. 45	9. 06
1959	13. 46	5. 59
1951–59 av	11. 58	6. 39
33-year av	13. 17	6. 66
NO AGUA (Weather Bureau station at Tres Piedras, 4 miles south of site)		
1954	9. 75	5. 86
1955	15. 89	5. 41
1956	6. 12	3. 23
1957	18. 70	6. 19
1958	11. 98	9. 69
1959	16. 40	5. 90
1954–59 av	13. 14	6. 05
41-year av	14. 78	7. 10

These records, supplemented by records from seasonal precipitation gages at each site, indicate that the Cebolla Mesa site was relatively drier than the No Agua site.

Temperature records at the nearest Weather Bureau stations show that the No Agua site was colder than the Cebolla Mesa site. During the years 1952 through 1959, the frost-free period averaged only 95 days at Tres Piedras compared with 118 days at Cerro. Mean monthly temperatures for April, May, and June were 41.1° F., 49.4°, and 58.1° at Tres Piedras and 43.3°, 51.8°, and 59.8° at Cerro, respectively.

PLANT RESPONSES

Herbage Production

Herbage production of the experimental pastures was affected more by weather conditions than by site or grazing treatments. Crested wheatgrass yields fluctuated greatly from year to year in response to varying precipitation. At Cebolla Mesa, for example, the average air-dry herbage yield ranged from 79 pounds per acre in the ex-

tremely dry year, 1956, to 653 pounds in 1954, a year of favorable moisture (table 3). The 8-year average yield was 424 pounds per acre. At No Agua, yields ranged from 95 to 834 pounds, and the 5-year average was 601 pounds per acre.

Differences in wheatgrass yields were closely related to October-through-May precipitation (fig. 3). Regression analyses by pasture showed that the relationships between yields and precipitation accounted for 61 to 94 percent of the variability in yields. Thus, the effects of fluctuating weather on yields was greater than any effects from differences between sites or among grazing treatments.

Grazing treatment had no significant effect on crested wheatgrass production. The responses to greater or lesser amounts of precipitation were virtually the same under the various intensities of grazing at the two sites. Relative differences in herbage yield between pastures at each site at the close of the experiment were about the same as at the beginning. Crested wheatgrass yields were different on the three pastures at both sites when the experiment started. These differences may have influenced yields at the end of the experiment. But when the initial differences were accounted for by covariance analysis, no effects attributable to grazing treatment could be detected. Actually, the pasture given heaviest grazing at Cebolla Mesa increased proportionately more in yield than the other two pastures, and at the end of the experiment the pasture subjected to heaviest grazing at No Agua had maintained production somewhat better than those subjected to the medium and lightest grazing.

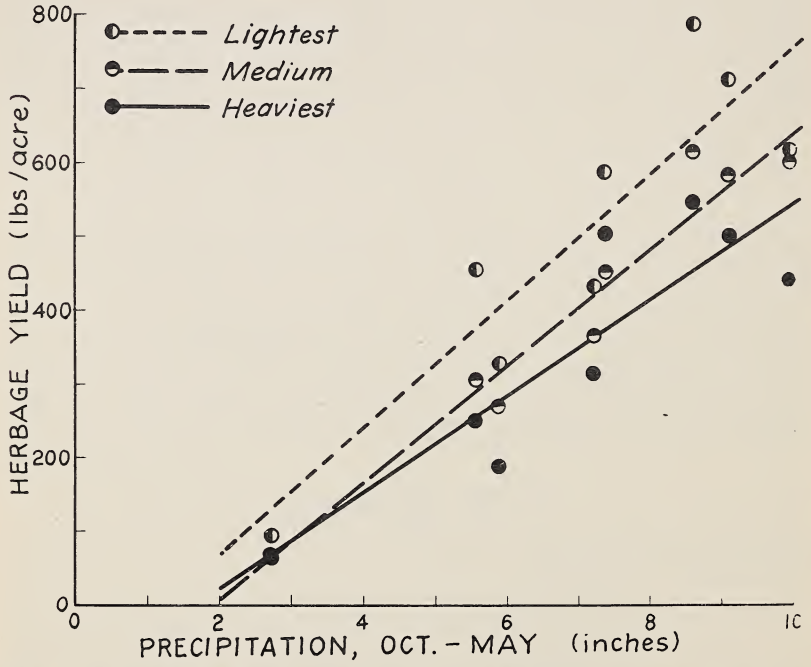


Figure 3.—Relationship between October-through-May precipitation and crested wheatgrass yields on Cebolla Mesa pastures grazed at three intensities. Correlation coefficients were 0.91 for lightest, 0.97 for medium, and 0.89 for heaviest grazing.

TABLE 3.—*Air-dry herbage yield of crested wheatgrass per acre on the experimental pastures*

Site and year	Heaviest grazing	Medium grazing	Lightest grazing	Average of three pastures	Exclosures
Cebolla Mesa:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1952	189	270	335	265	----------
1953	251	310	460	340	----------
1954	551	616	791	653	----------
1955	507	457	589	518	----------
1956	69	71	96	79	58
1957	447	605	624	559	476
1958	503	588	718	603	573
1959	318	366	436	373	289
Average	354	410	506	424	----------
No Agua:					
1955	770	893	839	834	----------
1956	60	116	109	95	54
1957	728	649	615	664	608
1958	593	762	768	708	746
1959	778	672	663	704	637
Average	586	618	599	601	----------

Differences in site also affect crested wheatgrass production. Table 4 shows yields on eight range seeding projects on National Forests in northern New Mexico. Yields were three or four times greater at the better sites characterized by higher elevation and higher average annual precipitation. The figures in this table also illustrate the dominating influence of current precipitation. Yields were 6 to 19 times higher in 1957, when ample moisture was received, than in 1956 when moisture was much below the long-time average throughout northern New Mexico.

Plant Heights

Plant heights were strongly influenced by weather. Like herbage production, culm heights of crested wheatgrass plants varied in response to October-through-May precipitation (fig. 4). Correlation coefficients of the relationships between culm height and October-through-May precipitation varied from 0.81 to 0.92, which indicated that at least two-thirds of the variability in culm heights observed was related to variation in precipitation.

The culm heights also reflect differences in growing conditions between the two sites. Plants at No Agua consistently had taller culms than plants at Cebolla Mesa.

Of special interest are the culm heights measured in 1956, when plants were under stress of extreme drought. Any effects of differential grazing during the previous 4 years at Cebolla Mesa on plant vigor should have influenced 1956 height growth. Average height of ungrazed plants under the heaviest grazing intensity was significantly less than under medium grazing. Moreover, the height of plants under medium grazing was less than that of plants under the lightest

TABLE 4.—*Crested wheatgrass yields in 1956 and 1957 for eight seedings located on the National Forests in northern New Mexico*

Site	Elevation	Estimated annual precipitation	Vegetation zone	Year seeded	Air-dry yield per acre	
					1956	1957
	Feet	*Inches*			*Pounds*	*Pounds*
Cebolla Mesa [1]	7, 450	13	Sagebrush-woodland.	1948	55	581
Taos County Land Project.	6, 600	14	Sagebrush	1949	79	879
No Agua [1]	8, 300	15	Ponderosa pine.	1949	99	1, 128
Chupadera	7, 000	16. 5	Sagebrush-woodland.	1951	188	1, 394
French Mesa	7, 800	17	Ponderosa pine.	1951	228	1, 374
Tio Grande	9, 250	17	do	1950	75	1, 415
San Antone	9, 000	17. 5	do	1949	101	1, 630
Laguna Larga	9, 500	18	Mixed conifer	1951	154	1, 553

[1] Data from project seedings surrounding experimental pastures.

intensity. The average difference between culm heights of plants under the heaviest and lightest grazing intensity in 1956 was about 1 inch. Two years earlier, in 1954, when moisture was favorable for growth, culm heights on these same pastures were essentially similar, with only 0.2 inch average difference.

Although culms were short in 1956, the greatest spread between pastures grazed at different intensities was measured in that year. The next year, 1957, a year of good precipitation, the differences in culm heights between grazing intensities largely disappeared. Plants under the heaviest grazing intensity were slightly shorter than those under lightest grazing each year, but regression analyses relating culm heights to antecedent precipitation showed no differences that could be attributed to grazing treatment.

Culm heights of plants on the No Agua showed the same trends as those on Cebolla Mesa. Most of the variation in height was associated with differences in growing conditions from year to year. Differences in grazing intensity had little or no consistent effect on height growth.

Basal Diameter

Basal diameters of individual crested wheatgrass plants on the experimental pastures apparently were affected by both grazing and weather. The evidence, however, was not clear-cut because the first measurements of basal diameter were not made until June 1955, the end of the fourth year of spring grazing at Cebolla Mesa and the end of the first year at No Agua. In that year, basal diameters averaged significantly larger on the pasture under lightest grazing at Cebolla Mesa and were about the same on the three pastures at No Agua. In 1957, the year following the severe drought, basal diameters were less than in 1955 on all pastures, as follows:

	Cebolla Mesa			No Agua		
	1955 (in.)	1957 (in.)	1959 (in.)	1955 (in.)	1957 (in.)	1959 (in.)
	----	2. 2	2. 9	----	2. 2	2. 0
Lightest grazing	2. 5	2. 0	2. 6	2. 6	1. 7	1. 4
Medium grazing	1. 6	1. 4	2. 0	2. 6	1. 3	1. 3
Heaviest grazing	1. 6	. 9	1. 6	2. 3	1. 3	1. 4

In 1957, basal diameters of plants at Cebolla Mesa averaged significantly larger inside the ungrazed exclosures and on the pasture under lightest grazing than on the other two pastures, and larger on the medium-grazed pasture than on the pasture under heaviest grazing. At No Agua, plants inside the exclosures were larger in diameter than those on the pastures, while plants on the pasture under lightest grazing were larger than those on the other pastures. These differences apparently can be attributed to the combined effects of drought and grazing, but the trend was toward smaller plant size with increased grazing intensity.

In 1959, diameters were larger than in 1957 at Cebolla Mesa, which indicated some recovery from the effects of the 1956 drought. Basal diameters of plants on the pasture under heaviest grazing were significantly smaller than on the medium-grazed pastures, and diameters on both these pastures were significantly smaller than those on the pasture under lightest grazing and inside the exclosures. Plants inside the exclosures at No Agua were larger in diameter than plants on the pastures, even though no differences were found between the pastures.

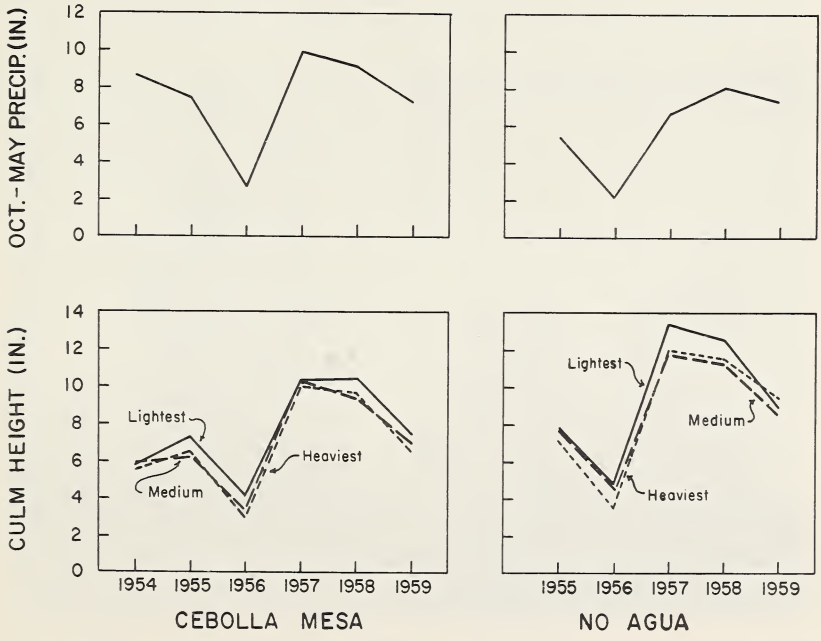


Figure 4.—Culm heights of crested wheatgrass at Cebolla Mesa and No Agua compared with October-through-May precipitation.

Growth Form

Detailed measurements of more than 6,000 individual crested wheatgrass plants in 1957 revealed that growth form was affected not only by differences in site conditions but also by past grazing treatment (Hickey 1961). At Cebolla Mesa, the driest of the sites, plants had a definite spreading form. At No Agua, intermediate as regards moisture conditions, plants were more nearly erect. At Collins Ranch, the wettest of the study sites, plants grew perpendicularly. These differences in growth form at the three study sites can be shown by the following ratios:

	Cebolla Mesa	*No Agua*	*Collins Ranch*
Crown diameter: Basal diameter	4. 2	2. 8	2. 5
Basal diameter: Leaf height	. 17	. 20	. 22

Grazing intensity had an even greater effect upon growth form. Plants that had undergone comparatively heavy grazing generally were more spreading or prostrate, whereas plants that had been lightly grazed were more erect in form (fig. 5). For example, on Cebolla Mesa the ratios of crown diameter to basal diameter were 2.85, 3.31, 4.71, and 7.32 for plants in the exclosure and under lightest, medium, and heaviest grazing, respectively. These differences in growth form were evaluated only in 1957, an unusually wet year.

Stand Conditions

Stand condition at the close of the study provides a critical test of the effects of different grazing treatments. Condition was evalu-

F—502668, 502669

Figure 5.—Differences in growth form of crested wheatgrass plants at No Agua under *A*, heaviest grazing, and *B*, lightest grazing.

ated by analyzing degree of plant fragmentation, formation of culms, number of dying plants, and establishment of young plants.

Plants became fragmented at both experimental sites. Large plants tended to form a number of smaller plants (fig. 6). The result was an increase in plants per unit area, together with a decrease in size of individual plants. The trend was toward a greater number of fragmented plants with increased grazing intensity (fig. 7). For example, after 4 years of grazing treatment at No Agua, 69 percent of the plants on the heavily grazed pasture were fragmented compared with only 43 percent under the lightest grazing and 32 percent under no grazing.

About the same percentage of plants formed culms under heaviest grazing as under lightest grazing. In fact, the trend was toward a slight increase in number of plants with culms as grazing intensity increased. A substantially higher percentage of plants was found with culms at No Agua than at Cebolla Mesa, presumably because moisture conditions were more favorable at the No Agua site in 1959.

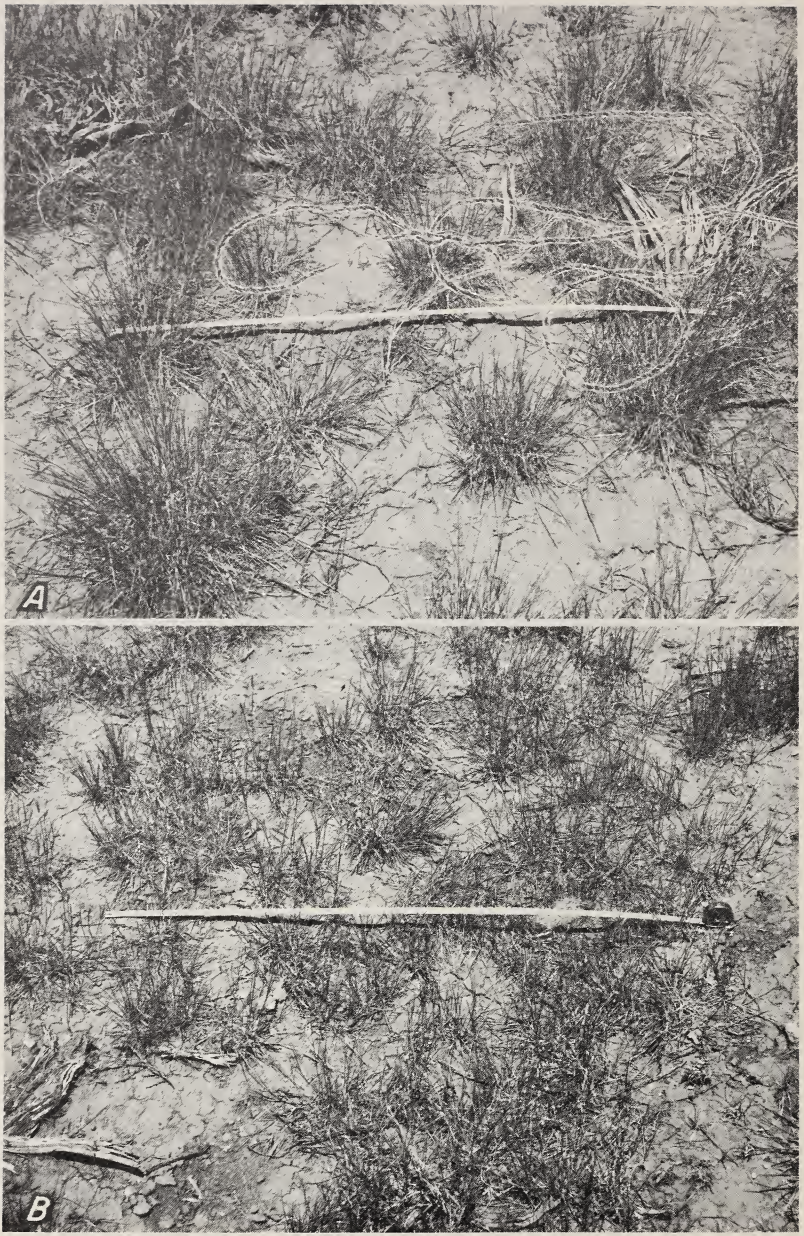
There were sufficient established young plants to replace weak and dead plants at all levels of grazing at Cebolla Mesa. There were also sufficient established young plants to replace weak and dead plants at the 34 and 56 percent utilization rates at No Agua, but not at 77 percent utilization. After 4 years of grazing treatment at the heaviest intensity at No Agua, an average of less than one established young plant per plot was found compared with more than one and a half dead or dying plants. Despite this evidence of deterioration in stand conditions, herbage production on this pasture was not reduced. Dying plants were judged according to the percentage of crown that was dead. For certain plants there was evidence that fragmentation preceded death loss, but for other plants large portions of the crown died without any signs of fragmentation. Young plants were considered well established if they had several leaves and were 3 inches or more tall and one-half inch or more in basal diameter.

The establishment of young plants under the different grazing intensities was not the same at the two sites. In general, as shown in figure 7, more young plants became established at No. Agua than at Cebolla Mesa, although there were approximately the same number of young plants under heaviest grazing at No Agua as at Cebolla Mesa. There were fewer young plants, however, than old plants that were three-fourths or more dead at No Agua. This seems to indicate reduced vigor of the seeded stand grazed at an average utilization of 77 percent for 4 years at No Agua, but not of the stand grazed for 7 years at an average of 69 percent at the drier Cebolla Mesa site.

Information was obtained on location of the young crested wheatgrass plants; whether they were growing in the open, in litter, under sagebrush, or in blue grama sod (table 5). More than 40 percent of the well-established young plants were found in open spaces away from mature plants and not in the accumulated litter (fig. 8). A possible explanation for the larger number of young plants found in the open is that there was less competition from the roots of mature plants.

At No Agua, about one-third of the young plants were found in accumulated litter—a smaller percentage than might be expected in view of the relatively arid environment of the site.

Approximately one-seventh of the young plants at No Agua were growing in living blue grama clumps; this was not expected since blue



F–502666, 502667

Figure 6.—Differences in fragmentation of crested wheatgrass plants at Cebolla Mesa: *A*, Slight fragmentation of plants under the lightest grazing; *B*, considerable fragmentation of plants under the heaviest grazing.

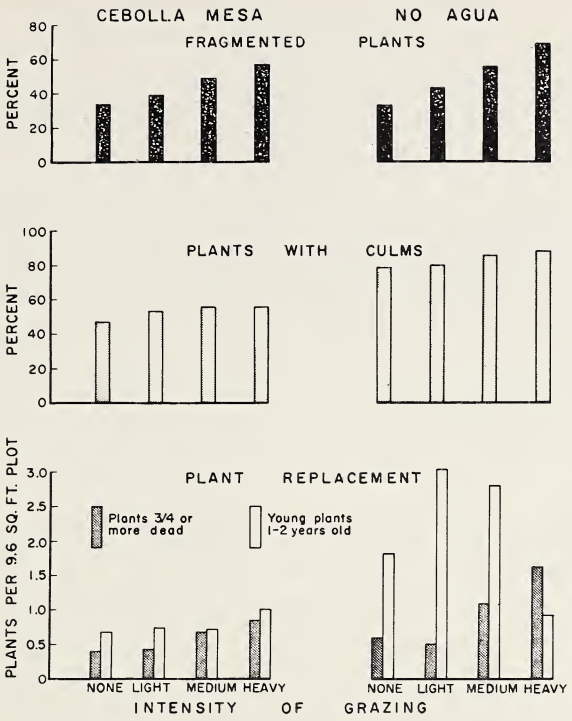
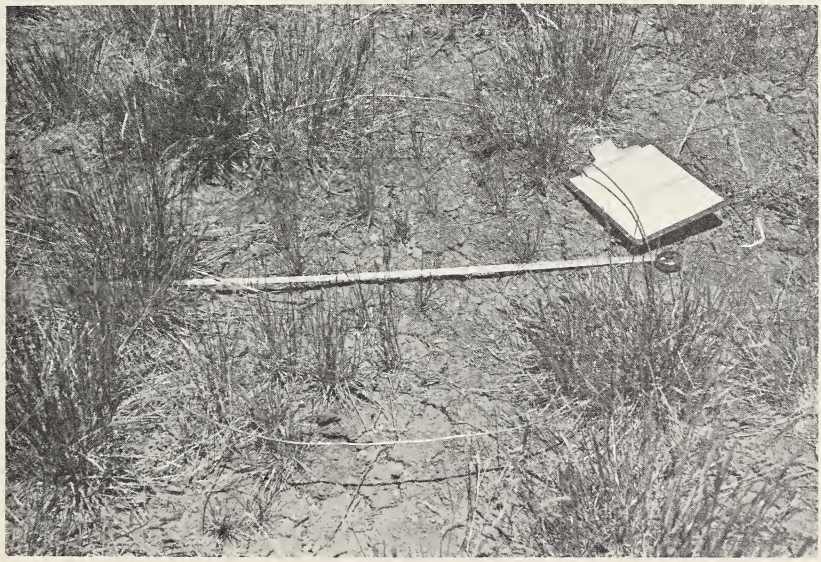


Figure 7.—Condition of the crested wheatgrass stands at the experimental sites in 1959.



F—502663

Figure 8.—Plot at No Agua shows several young plants of crested wheatgrass established in bare spots.

TABLE 5.—*Location of young crested wheatgrass plants* [1] *on the No Agua and Cebolla Mesa pastures, 1959*

Pasture and location of plants	Heaviest grazing	Medium grazing	Lightest grazing	Average of three pastures
No Agua:	*Percent*	*Percent*	*Percent*	*Percent*
In the open	49. 2	53. 1	43. 8	48. 7
In litter	40. 7	26. 6	40. 1	35. 8
In blue grama sod	8. 5	20. 3	14. 6	14. 5
Under dead sagebrush	0	0	0	0
Under live sagebrush	1. 6	0	1. 5	1. 0
Cebolla Mesa:				
In the open	45. 9	36. 1	45. 5	42. 5
In litter	48. 6	44. 4	31. 3	41. 4
In blue grama sod	1. 4	5. 6	7. 0	4. 7
Under dead sagebrush	2. 7	13. 9	15. 2	10. 6
Under live sagebrush	1. 4	0	1. 0	. 8

[1] 1- and 2-year-old plants that were well established at the time of observation.

grama forms a fairly dense sod and would seemingly compete effectively for moisture. At least two factors help to explain the presence of these young crested wheatgrass plants in blue grama sod: (1) the drought of 1956 may have weakened the blue grama to the point where crested wheatgrass could gain a foothold, and (2) crested wheatgrass grows at lower temperatures than blue grama and utilizes much of the available soil moisture early in the spring. Blue grama makes maximum growth later in the summer; hence, the two species are not entirely in direct competition for moisture.

Nearly the same percentage of young plants was found in accumulated litter as in the open at Cebolla Mesa. Few young plants were observed growing in blue grama sod, and practically none under live sagebrush plants. About 11 percent of the young plants were found under sagebrush plants killed by the plow during seeding operations. Apparently the dead brush gave enough shade and protection from drying to provide a suitable environment for seedling establishment. The live sagebrush plants, on the other hand, probably competed for moisture and any shading effects were nullified.

The effects of an increasing intensity of grazing on stand condition were a greater number of small plants due to fragmentation and a greater number of weakened or dying plants. Weakened or dying plants were being replaced by young plants in all pastures, however, except on the pasture under heaviest grazing at No Agua. The net effect was that numbers of plants were essentially the same under all intensities of grazing at both sites. Average number of plants per plot (9.6 square foot) in 1959 was as follows:

	Cebolla Mesa	*No Agua*
Not grazed	9. 5	7. 0
Lightest grazing	14. 9	12. 0
Medium grazing	16. 6	14. 2
Heaviest grazing	17.9	12. 1

Fewer but larger plants made up the stands in the ungrazed exclosures. The trend was toward a greater number of plants under the

heavier grazing at Cebolla Mesa, but this trend was not evident at No Agua.

Because there were no great differences in numbers of plants or percentage of plants with culms, it is concluded that the different grazing intensities did not materially affect stand condition, except possibly the average use of 77 percent at No Agua.

Ground Cover

Ground-cover changes under the various intensities of grazing were slight and apparently of minor significance. Despite trends toward more bare ground and less litter under the heaviest intensities of grazing, crested wheatgrass cover was affected very little by the different grazing treatments.

Because of the longer duration of the grazing intensity trials at Cebolla Mesa, results from that site may be somewhat more meaningful. Crested wheatgrass cover at the beginning and end of grazing treatments at Cebolla Mesa, in average number of hits [3] per transect, was as follows:

	1952	*1959*	*Change*
Lightest grazing	10.0	11.5	+1.5
Medium grazing	10.7	11.8	+1.1
Heaviest grazing	10.2	10.8	+ .6

Statistical analyses revealed no significant differences.

Data from more intensive sampling were available for comparing changes from 1955 to 1959. Even so, the results were the same: there were no significant changes in crested wheatgrass cover. Changes at Cebolla Mesa during this 4-year interval, in fact, were very minor (fig. 9). At No Agua, on the other hand, changes appeared larger, but statistical tests indicated these changes were no greater than might be expected by chance.

Cover of native perennial plants, including sagebrushes and rabbitbrushes, blue grama, and western wheatgrass, generally changed little during the period 1955–59. At Cebolla Mesa, changes in these native plants were slight indeed. At No Agua, however, changes were more erratic, particularly under heaviest grazing and inside the exclosures. On the pasture under heaviest grazing, a decrease in woody plant cover was offset by an increase in perennial grass cover. A similar change in plant cover also took place inside the exclosures. On these two areas at No Agua, snakeweed, which was included in the woody-plant category, decreased markedly during the 4 years, but blue grama increased.

As shown in figure 9, there were differences in litter cover due to grazing intensity; cover was inversely related to the grazing intensity on both areas. At Cebolla Mesa, the litter in 1959 was nearly the same as in 1955 regardless of grazing treatment. Litter cover remained about the same under the heaviest and medium intensities of grazing at No Agua. But comparatively large increases were recorded during the 4-year period under the lightest grazing and especially under no grazing. Differences in litter accumulated under the various grazing treatments were readily apparent in 1959 (fig. 10).

[3] "Hits" represent the occurrence of a basal part of a plant, litter, or other attribute within ¾-inch loops placed at 1-foot intervals along a 100-foot transect (Parker 1951).

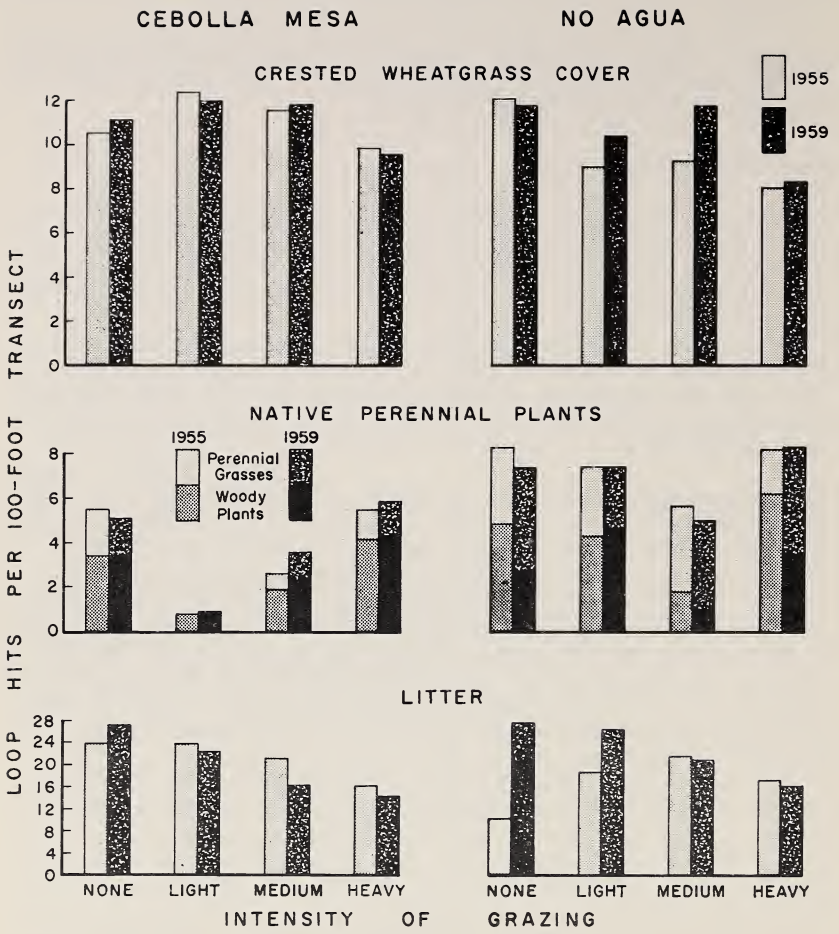
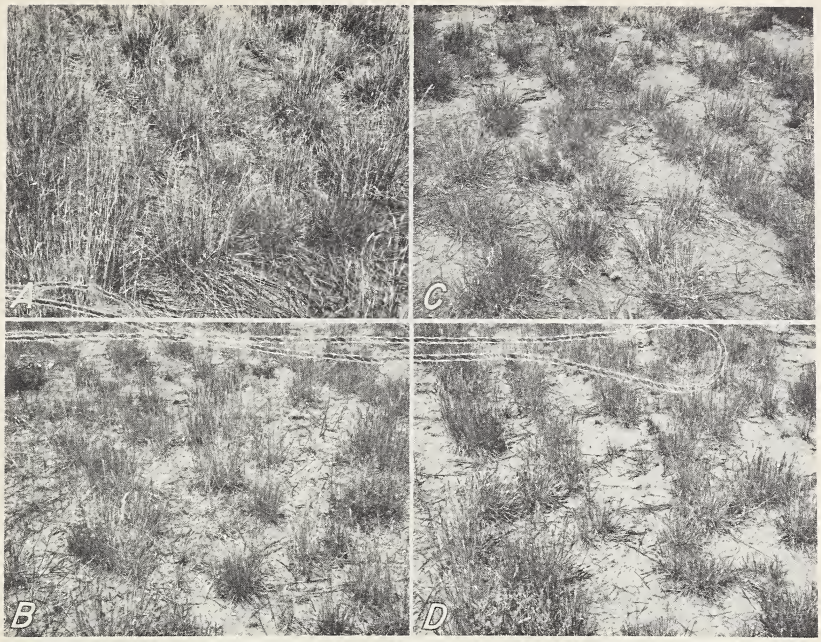


Figure 9.—Ground-cover comparisons for 1955 and 1959 under different grazing intensities.

From 1954 to 1958, the number of mature sagebrush plants increased under all intensities of grazing at Cebolla Mesa (fig. 11). Greatest increase in number of mature plants was on the pasture under heaviest grazing. Expressed in percent, the increases in number of mature plants from 1954 to 1958 were lightest grazing, 14.9; medium grazing, 33.3; and heaviest grazing, 49.9.

The percent of area covered by big sagebush crowns increased slightly under all grazing intensities from 1954 to 1958: 0.97 under the lightest grazing, 0.92 under the medium, and 1.56 under the heaviest (fig. 10). In terms of the 1954 stand of sagebrush, these represent increases of 44 percent, 45 percent, and 28 percent, respectively. These increases are all small, and covariance analysis indicates that any differences between grazing treatments were not significant.



F–502671, 502674, 502673, 502672

Figure 10.—Differences in crested wheatgrass cover, litter accumulation, and exposed bare soil at No Agua in 1959: *A*, Ungrazed exclosure; *B*, lightest grazing; C, medium grazing; and *D*, heaviest grazing.

Increases in the size of individual plants as well as in the number of plants classed as mature accounted for the increases in sagebrush cover on all pastures. Average increases in the crown size of individual mature sagebrush plants ranged from 20 to 52 percent on the three pastures:

	Crown area in square inches		
	1954	*1958*	*Percent increase*
Lightest grazing	126	192	52
Medium grazing	220	322	46
Heaviest grazing	172	206	20

The smallest increase in crown area of individual sagebrush plants was on the pasture under heaviest grazing, probably because of the number of new plants classified as mature.

Fewer young sagebrush plants (1 to 5 years old) were found on the pastures in 1958 than in 1954. Many included in the young-plant category in 1954 may have died, whereas others grew larger and were classed as mature plants in 1958. On the other hand, many of the young plants in 1958 had become established after 1954 (fig. 12). A similar number might become established in any subsequent 4-year period. The greatest number of young sagebrush plants in the seeded stands was found where most sagebrush was left alive after plowing. This points up the desirability of eliminating as many sagebrush plants as possible at the time of seeding to curtail reinvasion of the seeded stands.

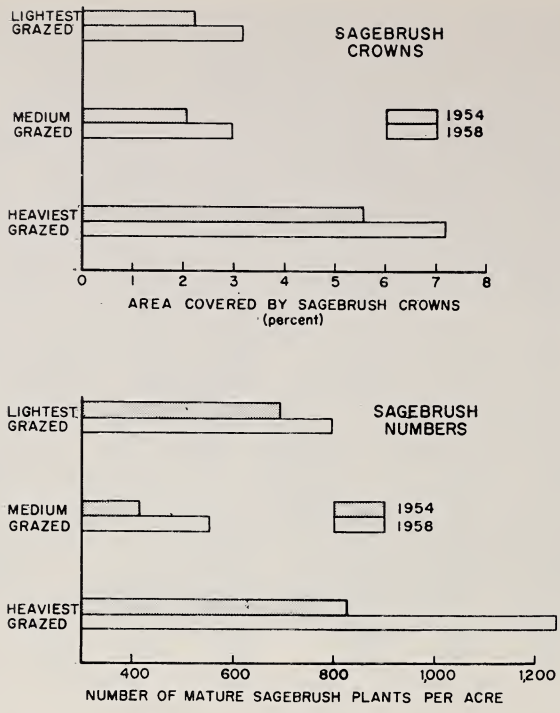


Figure 11.—Cover and number of big sagebrush plants on Cebolla Mesa pastures in 1954 and 1958.

The relationship between number of sagebrush plants 1 to 5 years old in 1958 and intensity of grazing for the 6 previous years was not significant.

A study made in 1959 on Cebolla Mesa indicated young sagebrush plants were more numerous where the crested wheatgrass cover was less dense. The ages of young plants, determined by growth rings, indicated sagebrush was not increasing as rapidly inside the ungrazed exclosures as on the pastures. No relationship was found between number of young sagebrush and distance to mature sagebrush plants. Although some small plants were found near large mature sagebrush, many of the young plants were in open spots 10 to 25 feet from such plants.

Summary of Plant Responses

Plant responses generally were affected more by weather and site than by differences in grazing intensity. Effects of year-to-year fluctuations in precipitation, particularly October-through-May precipitation, tended to overshadow the effects of grazing treatments. Herbage yields and culm heights varied widely in response to differences in precipitation. The somewhat more favorable site for growth of crested wheatgrass at No Agua than at Cebolla Mesa was manifested by higher herbage yields, taller culms, a greater number of young crested wheatgrass plants, and more litter accumulation. Also, a higher percentage of plants produced culms and the plants had a more erect shape at No Agua.

F–502665, 502670

Figure 12.—Young plants of big sagebrush on Cebolla Mesa: *A*, Ring counts indicated plants the size of the one by the rule were 4 or 5 years old; *B*, young plants the size of the one the technician is touching and the plant at the lower left of the milacre plot were 2 or 3 years old, according to ring counts.

Increasing grazing intensity resulted in fragmentation of crested wheatgrass plants into more plants of smaller size. Also, the proportion of dead crowns of wheatgrass increased. On the other hand, the establishment of young crested wheatgrass plants was sufficient to replace losses, so the net effect was that stands were maintained satisfactorily under all grazing intensities, with one possible exception.

Any grazing of crested wheatgrass tended to reduce litter accumulation, and the heavier the intensity of grazing the less the accumulation. Some litter accumulated under all grazing intensities.

Increasing grazing intensity also had a tendency to affect growth form of the individual plants by changing them from an erect to a spreading form. The number of plants producing culms, however, and the culm heights were not affected appreciably, except during a drought year. Neither was total herbage production affected by the different grazing intensities. Sagebrush crown cover increased under all grazing intensities, and the establishment of young plants of big sagebrush was not shown to be related to grazing intensity.

The general conclusion that can be drawn from the foregoing is that crested wheatgrass stands were maintained satisfactorily under all intensities of grazing tested. Herbage yield held up under even the highest intensity of use, and crested wheatgrass plants that died were replaced by young plants on all pastures except one. The exception was the No Agua pasture grazed at an average of 77 percent. Under this level of use, not enough young plants were being produced to offset plant mortality. The stand, however, was being maintained satisfactorily in all other respects.

Another general conclusion is that sagebrush became reestablished under all grazing intensities.

Because the spring grazing period lasted only about 30 days, the wheatgrass plants had ample time for regrowth during the remainder of the growing season. Northern New Mexico usually receives sufficient summer rainfall to cause crested wheatgrass to regrow after it is grazed whenever temperatures are favorable. Regrowth, in fact, was observed nearly every summer or fall. Thus the plants were able to grow and reproduce, even where spring grazing was heaviest.

NUTRITIVE VALUE

Samples of crested wheatgrass herbage collected at Cebolla Mesa and No Agua in May of 1955 and 1956 were analyzed for nutrients. When samples were collected, the grass was green and succulent, with leaves 4 to 6 inches long. Chemical analyses showed crude protein content ranged from 11.0 to 19.3 percent and crude fiber from 17.8 to 26.2 percent (Pingrey and Dortignac 1959). Other samples of crested wheatgrass were collected in May 1954 at the Collins Ranch site. Chemical analysis and digestion experiments with sheep showed the following (Watkins 1955):

Chemical analysis

crude protein	19.8	percent
calcium	.41	percent
phosphorus	.19	percent
carotene	96.2	mg./lb.

protein	84.8 percent
crude fiber	79.3 percent

These figures indicate that the nutrient content of crested wheatgrass herbage in May is more than adequate to meet requirements of beef cattle. Studies elsewhere in New Mexico have shown that 0.113 percent phosphorus and 0.227 percent calcium in forage meet the requirements of breeding cows for the summer (Knox, Benner, and Watkins 1941). Recommended minimum levels of forage protein are 6 percent for mature pregnant cows and 9 percent for beef cows during lactation (Watkins 1943).

Total digestible nutrients (TDN) for the wheatgrass were 71.1 percent, which is higher than for alfalfa hay. Digestibility studies with cattle at Benmore, Utah, in 1956 and 1957 showed that crested wheatgrass contained 7.8 percent digestible protein and 55.6 percent TDN during the period May 28 to June 13, but during the next 2-week period the digestible protein dropped to 3.0 percent and TDN to 50.0 percent (Cook and Stoddart 1961).

Daily gains of cows and calves followed the same pattern as nutrients; cows averaged 1.2 pounds during the first 2 weeks but only 0.6 pounds during the next 2 weeks, while calves gained 2.5 pounds the first period and only 1.1 the second. These results emphasize the advantage of grazing crested wheatgrass early in the season while nutritive values are higher.

CATTLE GAINS

Daily Gains

Daily gains of the cattle varied from year to year as weather and forage conditions changed. Differences in grazing intensity were reflected in average gains to varying degrees, which depended on class of cattle.

Average daily gain per head of cows grazed on Cebolla Mesa varied by the year and grazing intensity from 1.56 to 4.76 pounds (table 6). Daily gains of the cows at Cebolla Mesa were generally exceptionally high, probably because the cows came to the experiment from the winter range in extremely thin condition. In 1953 and 1954 gains were higher than in other years, mainly because utilization of the crested wheatgrass averaged considerably less on all pastures than during subsequent years. In 1956, gains were much lower on the average than in the other years because of the very dry year. On the average, cows gained more per day under the lightest grazing than under the medium or heaviest grazing, and more under the medium than the heaviest grazing.

Calves on Cebolla Mesa gained an average of 1.51 to 2.85 pounds a day. The differences in daily gains between the lightest, medium, and heaviest grazing were not significant. Average daily gains were lowest in 1956 and highest in 1953.

Because utilization was somewhat different on the pastures each year, the relationship of daily gains to the degree of grazing on crested wheatgrass was studied for both the cows and calves on Cebolla Mesa (fig. 13). Average daily gains of cows were inversely related

TABLE 6.—*Average daily gain per head of cows and calves on the Cebolla Mesa crested wheatgrass pastures, 1953–58*

Class of cattle and year [1]	Daily gain per head			
	Heaviest grazing	Medium grazing	Lightest grazing	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*
Cows:				
1953	2. 90	4. 40	4. 49	3. 93
1954	4. 17	4. 67	4. 44	4. 43
1955	2. 66	2. 82	4. 46	3. 31
1956	1. 89	1. 56	3. 75	2. 40
1957	1. 85	2. 68	4. 76	3. 10
1958	2. 84	3. 20	3. 48	3. 17
Average	2. 72	3. 22	4. 23	3. 39
Calves:				
1953	2. 85	2. 48	2. 76	2. 70
1954	2. 44	2. 59	2. 11	2. 38
1955	2. 27	2. 14	2. 66	2. 36
1956	1. 51	1. 62	1. 79	1. 64
1957	1. 90	2. 05	2. 57	2. 17
1958	1. 80	1. 91	2. 12	1. 94
Average	2. 13	2. 13	2. 34	2. 20

[1] 1952 cattle gains were not included because dry cows and heifers were used as test animals that year.

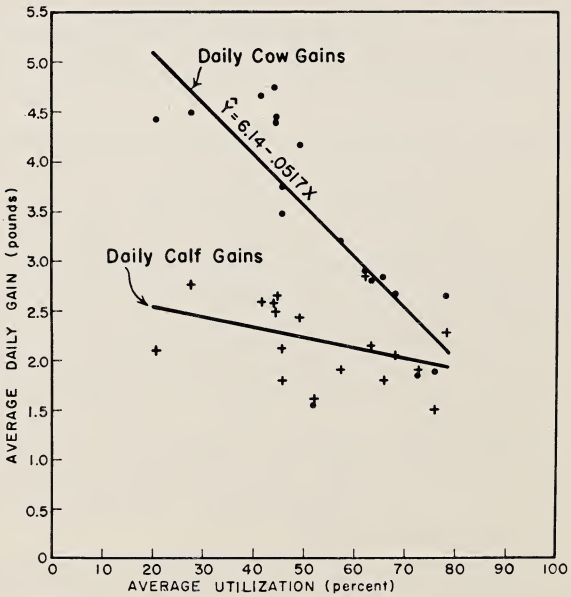


Figure 13.—Relationships between daily gains of cows and calves and average percent utilization of crested wheatgrass for the years 1953 through 1958 on Cebolla Mesa.

to percent utilization. The correlation coefficient between gains and degree of utilization was −0.785. This was significant at the 0.05 probability level. A correlation coefficient between gains on calves and degree of utilization of −0.417 was not significant. The cows must have been able to give sufficient milk to produce good gains on their calves, even under heavy grazing.

Yearling cattle gained about 2 pounds a day in most years on No Agua (table 7). A regression analysis showed no consistent relationship between daily gain of yearlings and grazing intensity. In 2 years they gained the most under the heaviest grazing, whereas in the other 2 years highest gains were made under lightest grazing.

TABLE 7.—*Average daily gains per head of yearling cattle on the No Agua crested wheatgrass pastures, 1955–58*

Year	Daily gains per head			
	Heaviest grazing	Medium grazing	Lightest grazing	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*
1955	2. 08	2. 06	1. 65	1. 93
1956	1. 31	1. 71	1. 99	1. 67
1957	1. 55	3. 11	3. 50	2. 72
1958	2. 40	2. 21	2. 20	2. 27
Average	1. 84	2. 27	2. 34	2. 15

Gains Per Acre

Cattle gains per acre fluctuated widely from year to year with weather conditions and amounts of forage produced. At Cebolla Mesa, for example, gain per acre varied from a low of 9 pounds on the pasture under lightest grazing in 1956 to a high of 50 pounds on the pasture under heaviest grazing in 1958 (table 8). Highest gains per acre at Cebolla Mesa were obtained in 1958, 1955, and 1954—3 years of greater forage production. Lowest gain per acre on all three pastures resulted from spring grazing in the drought year of 1956.

Total cattle gain per acre at Cebolla Mesa was greatest under the heaviest grazing, intermediate under the medium grazing, and least under lightest grazing (table 8). This relationship held for all years but 1953. Similar differences due to grazing treatments were found for 3 of the 4 years of experimental grazing at No Agua, where yearlings were grazed. This finding differs from results obtained at Benmore, Utah, where gains per acre under heavy grazing dropped below those obtained under medium grazing after only 2 years of treatment (Frischknecht et al. 1953). Heavy grazing was 80 percent utilization, however, at Benmore.

Calf gains contributed less than half of the total gain per acre each year on all pastures at Cebolla Mesa (fig. 14). Of the total gain per acre, heaviest grazing produced the highest proportion as calf gain and lightest grazing the lowest proportion as calf gain.

TABLE 8.—*Cattle gains per acre on the Cebolla Mesa and No Agua experimental crested wheatgrass pastures*

Location, class of cattle, and year [1]	Cattle gain per acre			
	Heaviest grazing	Medium grazing	Lightest grazing	Average
Cebolla Mesa (cows and calves):	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1953	30. 5	31. 2	22. 7	28. 1
1954	37. 3	35. 1	21. 8	31. 4
1955	45. 5	30. 5	24. 1	33. 4
1956	15. 1	10. 9	9. 4	11. 8
1957	25. 3	20. 1	17. 2	20. 9
1958	49. 8	38. 3	23. 7	37. 3
Average	33. 9	27. 7	19. 8	
No Agua (yearlings):				
1955	50. 1	41. 5	19. 9	37. 2
1956	17. 3	16. 9	13. 3	15. 8
1957	17. 2	25. 7	26. 2	23. 0
1958	38. 3	31. 4	21. 1	30. 3
Average	30. 7	28. 9	20. 1	

[1] 1952 cattle gains at Cebolla Mesa were not included because dry cows and heifers were used as test animals that year

This results from the greater influence of grazing intensity on cow gains than calf gains. Ranchers who operate on a cow-calf basis are primarily concerned with pounds of calf gain rather than with total gain of cows and calves. When heavy grazing causes poor condition in the cow, however, it can affect her breeding and calving. Such effects were not determined in this study. Spring gains of 1.5 to 2.0 pounds per day on breeding cows, however, are usually considered satisfactory.

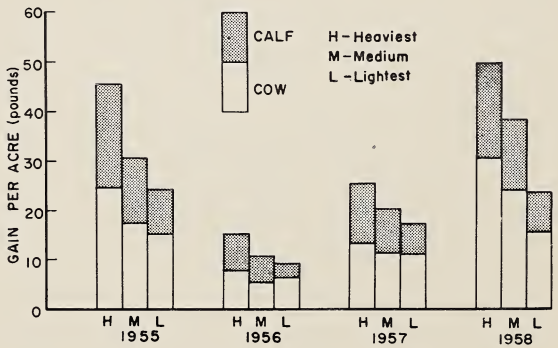


Figure 14.—Contributions of cows and calves to the total gains per acre under three intensities of grazing at Cebolla Mesa, 1955–58.

Native Range Versus Crested Wheatgrass

Gains of cows and calves on the crested wheatgrass pastures were substantially greater than on the nearby native range on Cebolla

Mesa (fig. 15). Daily gains of cows on the native range during the 5 years 1953 through 1957, when cattle on native ranges were weighed, averaged only 1.21 pounds a day compared with 3.23 pounds a day on the crested wheatgrass grazed at the medium rate (table 9). Average daily gain of the calves was 1.16 pounds as against 2.18 pounds on the crested wheatgrass.

It was possible to compare the gains of yearling cattle on crested wheatgrass with their gains on nearby native range at No Agua in only one year, 1955. Thirteen yearlings made average gains of 1.98 pounds a day on crested wheatgrass compared with only 1.50 pounds a day on the native range. The native range grazed on No Agua was open pine type in somewhat better condition than the crested wheatgrass area before it was seeded.

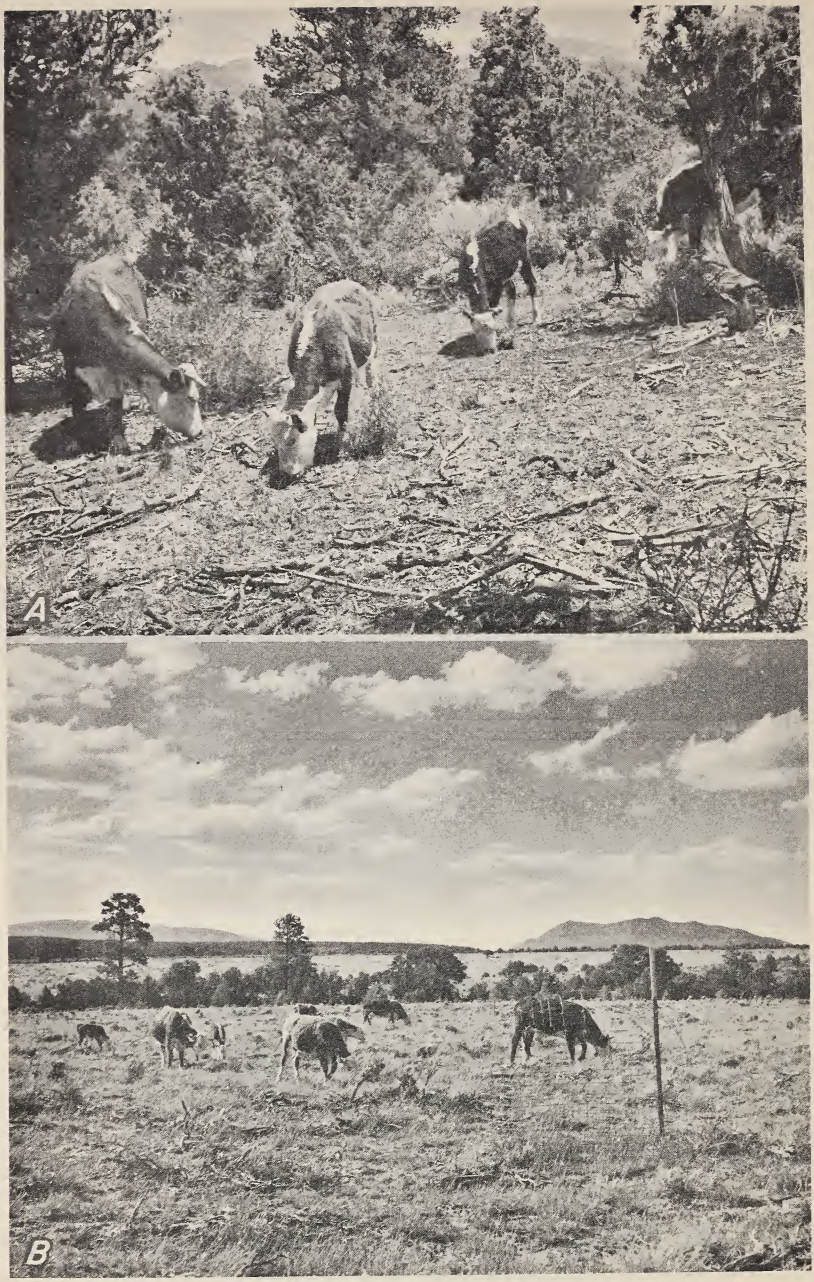
TABLE 9.—*Comparisons between daily gains per head of cows and calves on native range and crested wheatgrass pastures under medium grazing, Cebolla Mesa, 1953–57*

Year	Daily gain per head of cows		Daily gain per head of calves	
	Native range	Medium grazing, crested wheatgrass	Native range	Medium grazing, crested wheatgrass
	Pounds	*Pounds*	*Pounds*	*Pounds*
1953	1. 55	4. 40	1. 00	2. 48
1954	1. 67	4. 67	1. 46	2. 59
1955	. 19	2. 82	1. 00	2. 14
1956	1. 90	1. 56	. 93	1. 62
1957	. 74	2. 68	1. 43	2. 05
Average	1. 21	3. 23	1. 16	2. 18

Although it must be recognized that on both areas the native range sites were not comparable to the seeded sites, the comparisons show the advantage of using ranges seeded to crested wheatgrass to supplement native ranges as a source of green forage for growing beef animals and lactating cows with young calves. Supplementing deteriorated native range in this manner is particularly beneficial.

Summary of Cattle Responses

Daily gains of cows were inversely related to intensity of grazing. Cows gained 55 percent more per day under the lightest grazing than under the heaviest. Of more significance, however, are the calf gains, because calves usually are the marketable product in northern New Mexico. Differences in daily gain per head for calves under the different grazing intensities were not significant. No differences in daily weight gains between grazing intensities were found for yearlings, but the results were considered inconclusive.



F—502656, 502658

Figure 15.—Cattle grazing on Cebolla Mesa: *A*, Native range with sparse herbaceous cover and abundance of woody vegetation; *B*, cattle from same herd grazing experimental pasture of crested wheatgrass.

Gains per acre were strongly influenced by the level of stocking. All classes of cattle gained the most per acre under the heaviest stocking. Calf gains per acre were more than 100 percent higher under the heaviest stocking than under the lightest stocking, and 50 percent more than under medium stocking. Yearling gains per acre averaged 50 percent higher under the heaviest and medium stocking than under the lightest stocking.

The foregoing suggests that, for spring grazing on crested wheatgrass, the higher intensities of use result in maximum calf or yearling production. In a cow-calf operation, the condition of the cow is also important. These studies showed that heavier grazing curtailed weight gains on the cows even on the thin animals used in the study. An average daily gain of 1.85 pounds, the least recorded on the pasture under heaviest grazing, however, seems adequate for breeding animals.

The advantages of crested wheatgrass for spring cattle grazing are shown by comparisons with native range. Calves gained a pound more per day on crested wheatgrass than on adjacent native range of low quality. Yearlings gained 0.5 pound more.

MANAGING CRESTED WHEATGRASS STANDS

Recommended Intensity of Use

Evidence from all phases of the experiment indicates that an average intensity of up to 65 or 70 percent utilization by weight during a month-long spring season is satisfactory under northern New Mexico conditions. When crested wheatgrass range was grazed at this intensity, stands were maintained and cattle gains were satisfactory. Light grazing of crested wheatgrass may be an undesirable practice. For not only was the grazing spotty, but also numerous upright, coarse-stemmed plants with accumulations of old growth (so-called "wolf plants" that remain ungrazed year after year) were found on stands utilized less than 50 percent.

Although not entirely conclusive, the results indicate further that repeated removal of more than 75 percent of the herbage during the spring season may produce undesirable changes in the seeded stands. These changes include excessive fragmentation and weakened vigor of mature plants, and scarcity of litter and young plants.

The 70-percent herbage removal refers to growth produced by the end of the spring grazing period and not to growth produced during the entire year. In northern New Mexico, due to summer rains, some additional growth usually is made in the summer and fall, and in cool, moist summers this regrowth may be considerable. Regrowth was observed nearly every year. In 1955, for example, up to 370 pounds of regrowth per acre was measured at the experimental sites. This regrowth undoubtedly plays an important role in maintaining the plants in vigorous condition under the relatively heavy spring use received.

Year-to-year variation in degree of use is to be expected because it is difficult to stock to obtain a prescribed degree of utilization on spring range. The principal problem is that crested wheatgrass growth is affected by precipitation and temperature during the period the animals are grazing. Herbage available to the cattle may be altered appreciably by cool, wet weather or hot, dry weather during

the grazing period. As a result, even though the long-term aim of stocking is to obtain an average utilization of between 65 and 70 percent, utilization may be less in some years and more in other years. The crested wheatgrass stand probably will not be permanently damaged if utilization occasionally exceeds 75 percent when grazing is for the short spring period. An exception would be during drought. Precautions should be taken during years of deficient overwinter precipitation to insure that utilization is not excessive.

Stocking

Stocking depends on amount of herbage produced. This varies from year to year on a single site and from site to site.

Variation in herbage production on the experimental sites is illustrated by figure 16. Production was more than seven times higher in 1958, when precipitation was high, than in 1956, when precipitation was less than half the long-time average. Such variations show the need for flexibility in herd management. This is especially true when very low stocking is necessary during drought years (figs. 17 and 18).

When herbage production is high, stocking can be relatively heavy. Conversely, when herbage production is low a greater acreage must be allowed for each animal unit of grazing. On the two experimental areas, for example, stocking rates, herbage yields and the resulting utilizations during the drought year 1956 and the good growing year 1958 were as shown in table 10. In using such relationships to guide

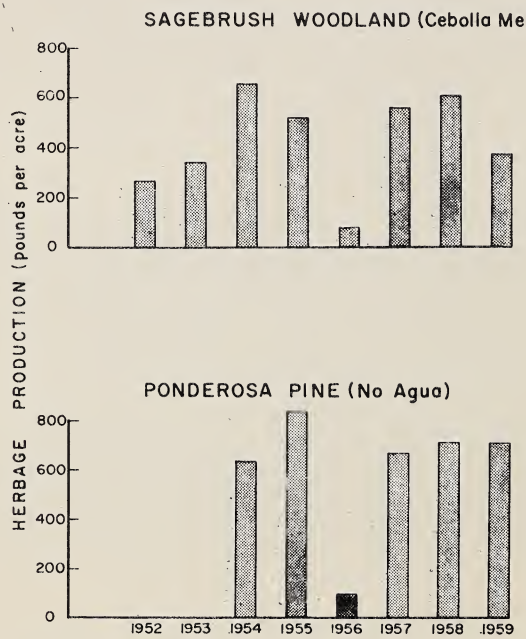
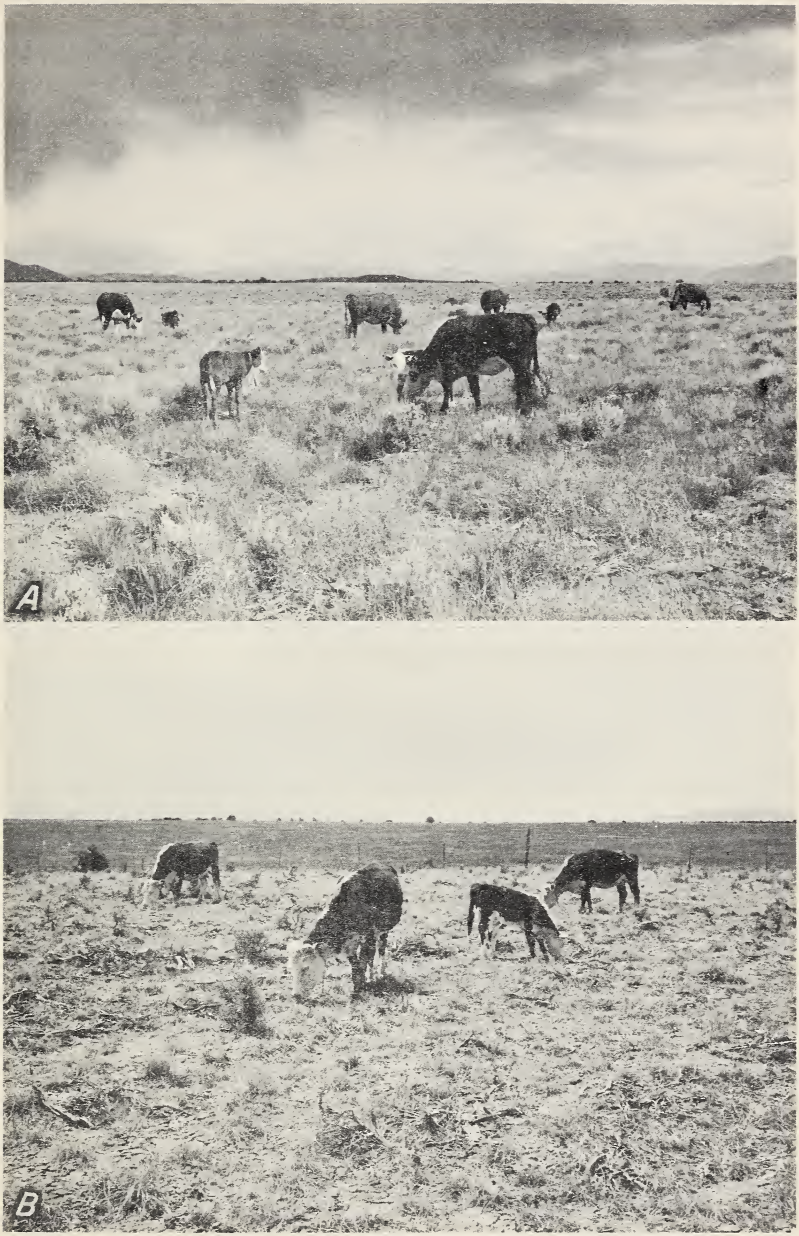
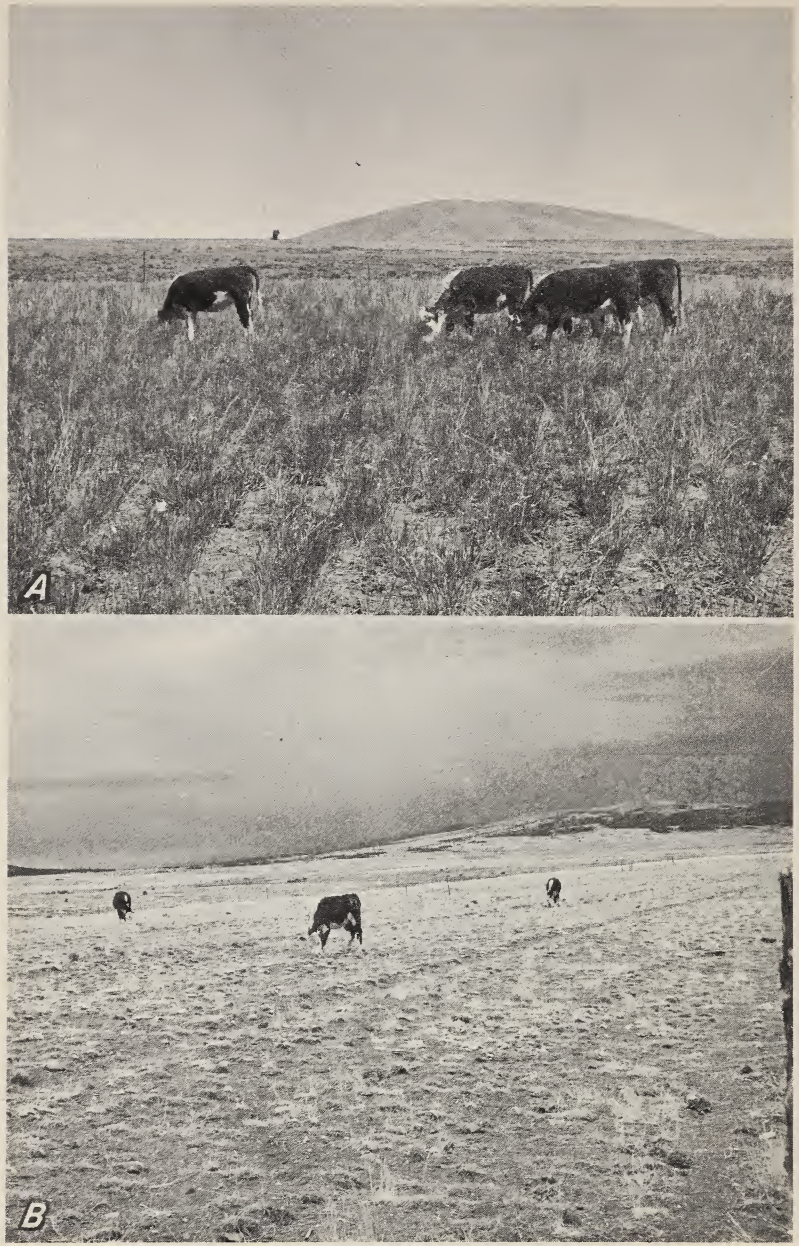


Figure 16.—Fluctuations in herbage production of crested wheatgrass in the sagebrush-woodland zone, represented by the Cebolla Mesa site, and in the ponderosa pine zone, represented by No Agua, 1952–59.



F—502662, 502661

Figure 17.—Flexibility in management will be necessary because of year-to-year variations in herbage production, as illustrated by these differences in forage available for grazing under lightest stocking at Cebolla Mesa in *A*, the relatively wet year 1958 and *B*, the extremely dry year 1956.



F–502664, 502660

Figure 18.—Year-to-year differences in forage conditions at No Agua by the end of the third week of grazing: *A*, Under the lightest grazing in the relatively wet year 1958, and *B*, under medium grazing in the drought year 1956.

stocking of large seeded ranges, allowance for poorer distribution of cattle is necessary.

TABLE 10.—*Herbage yields, stocking rates, and utilization of experimental pastures during 1956, the year of poorest plant growth, and 1958, a year of good growth*

Year	Cebolla Mesa			No Agua		
	Yield	Stocking	Utilization	Yield	Stocking	Utilization
	Lbs./acre	*Acres/AUM*	*Percent*	*Lbs./acre*	*Acres/AUM*	*Percent*
1956	69	5. 0	76	60	3. 0	77
	71	7. 0	52	116	4. 1	76
	96	14. 2	46	109	6. 0	38
1958	503	2. 2	66	593	2. 5	79
	588	3. 2	57	762	2. 8	38
	718	5. 4	45	768	4. 2	27

Prediction of herbage yield in advance of the grazing season would assist the range manager in stocking crested wheatgrass range. Figure 3, p. 14, shows that good relationships exist between October-through-May precipitation and herbage yield during the spring grazing season. The manager, however, needs some basis for estimating yields before the end of May. He could use a weaker relationship found to exist between herbage yields and October-through-March precipitation for the 2 previous years on the study areas. A correlation coefficient of 0.795 was found in the lower ponderosa pine zone between precipitation during the October-through-March period for the 2 previous years and the herbage yields. Likewise, a correlation coefficient for this relationship of 0.681 was found for the sagebrush woodland zone (fig. 19).

Use of estimates from such relationships should be regarded only as rough guides to yields subject to considerable error. In a region such as northern New Mexico where herbage production may vary as much as 10 to 20 times in succeeding years, such guides, however, should be very useful. The range manager could anticipate the relative herbage yields well in advance of the date the animals are turned into the seeded stand. This should facilitate closer integration between seeded and native range where crested wheatgrass range carries a significant portion of the grazing load.

Crested wheatgrass should make substantial growth before the cattle are turned on the seeded stand in the early spring. At the Cebolla Mesa site the yield of crested wheatgrass about May 1 averaged 54 percent of the mid-June yield, so that slightly more than half of the total herbage available for grazing during the spring season was produced before the cattle started grazing. Estimates of available forage at this time may serve as a guide for adjustments in stocking rate.

Weather conditions in April and May influence the availability of crested wheatgrass forage for spring grazing. In two of the study years nearly two-thirds of the total growth was made by the first week in May; mean temperatures for April in these years were well above

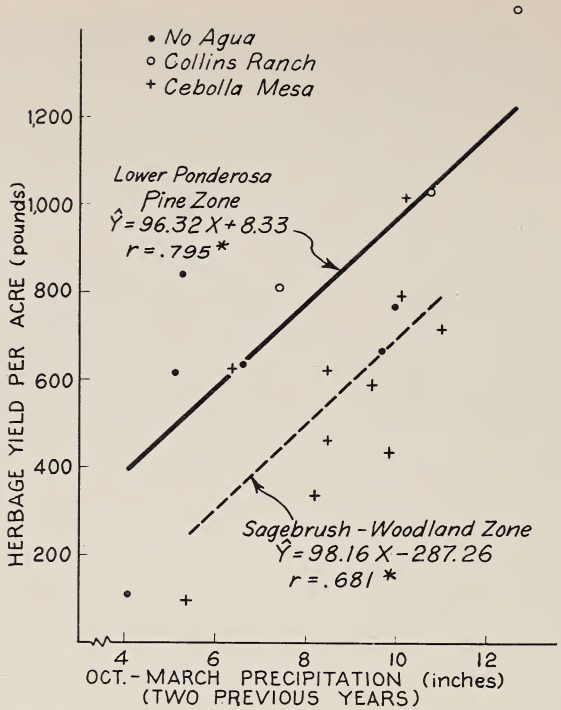


Figure 19.—Regression lines for predicting herbage yields of crested wheatgrass in advance of the spring grazing season.

the long-term average. By contrast, in 1 year only 35 percent of the total growth was made by the start of the grazing season; that year was marked by below-average temperatures in April and May, and 1 inch above-average precipitation in May. In the very dry year 1956, the grass made no growth during the grazing period.

The safest practice appears to be to delay early spring grazing until the maximum leaf length of the crested wheatgrass is 4 or 5 inches, which usually will be about May 1 in most years in northern New Mexico. But the leaves may reach this length any time from April 15 to May 15, depending on weather conditions.

Methods of Estimating Utilization

Utilization estimates are necessary to insure proper use of the seeded stand. These estimates should be made 2 to 3 weeks after cattle are turned on the grass in the spring and again toward the end of the grazing season. By adjustment of either numbers of cattle or length of the grazing period, utilization can be kept within reasonable limits.

Three methods have been used satisfactorily for determining utilization of crested wheatgrass in northern New Mexico. These are the (1) ocular estimate-by-plot, (2) actual weight or difference, and (3) grazed-plant methods (Natl. Acad. Sci.—Natl. Res. Council 1962). To provide reliable utilization estimates with the ocular estimate-by-

plot method, careful training and checking are necessary. The difference method, while it is usually more accurate on individual plots, requires extra expense and effort because of the need for clipping and for large numbers of cages to protect plants from grazing. The grazed-plant method generally is less accurate than these two methods but has the advantages of being rapid and easy to use.

The grazed-plant method was found to provide quick approximations of utilization. With this method, the number of grazed and ungrazed plants are counted and expressed as a percentage of the total number of plants observed. This is converted to an estimate of herbage utilization by weight through use of regression relationships. Figure 20 shows this relationship based on the 7 years of grazing at Cebolla Mesa and 4 years at No Agua. The method has been successfully applied to several other perennial grasses growing under a variety of environmental conditions (Hurd and Kissinger 1953; Mattox 1955; Roach 1950).

Paced transects are a convenient way of obtaining the counts of grazed and ungrazed plants. The observer selects a random starting point and direction of travel, and keeps a tally of grazed and ungrazed plants touched by a point marked on his toe. One hundred plants should be observed to make up each utilization estimate, and a number of estimates would be needed on a large range area. The number needed would vary with the size of the range, spottiness of use, topography, and other factors. Time records showed that only 5 minutes are required to observe and record 100 plants along a paced transect.

A limitation of the grazed-plant method when used with crested wheatgrass is that it does not detect the higher degrees of utilization. Thus, the method did not detect utilization greater than 70 to 80 percent under spring cattle grazing because 100 percent of the plants were grazed. This limitation is useful because 70 percent

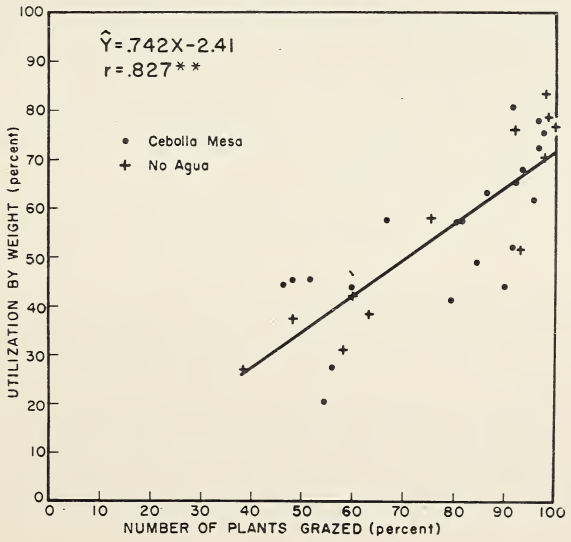


Figure 20.—Relationship between number of plants grazed and utilization by weight.

utilization is the maximum that crested wheatgrass should be grazed. When nearly all the plants have received some grazing, even though individual plants may not have been grazed heavily, the range has been grazed all it should if it is to be maintained in productive condition.

SUMMARY AND CONCLUSIONS

Crested wheatgrass was grazed at different intensities by cattle for a month-long spring season from 1952 through 1958 at one site and from 1955 through 1958 at another site in northern New Mexico. Cows and calves were used as test animals at one site and yearlings at the other. The main objective was to determine the optimum intensity of grazing crested wheatgrass by cattle during the May–June period.

Effects of the different intensities of grazing on crested wheatgrass stands and cattle gains were evaluated. Utilization of the wheatgrass averaged 41, 55, and 69 percent on three pastures for 7 years at one site, and 34, 56, and 77 percent for 4 years at the other site. The utilization percentages were of the weight produced by the end of the grazing period; they did not include the regrowth that was made on all pastures after the cattle were removed.

Grass yields, stocking rates, plant heights, and cattle gains varied greatly from year to year in response to differences in precipitation.

Herbage production varied from less than 100 pounds per acre during a drought year to more than 800 pounds in a year of favorable moisture. No differences in crested wheatgrass yields resulted from the different grazing intensities.

Increasing the intensity of grazing resulted in greater fragmentation of crested wheatgrass plants, and a higher percentage of plants with three-fourths or more of the crown dead. Reproduction was sufficient to replace such plants under all intensities, except on the pasture grazed at an average of 77 percent for 4 years. Nevertheless, herbage production and cover of crested wheatgrass were maintained satisfactorily on this pasture.

Increasing the intensity of grazing also had a tendency to change crested wheatgrass from an erect to a spreading growth form. The proportion of plants producing culms, however, and the height of culms were not affected appreciably.

Litter accumulated under all grazing intensities, but the accumulation was less under all grazing intensities than where no grazing occurred. Also, litter accumulation was inversely related to grazing intensity.

Big sagebrush cover increased about the same under all intensities of grazing, but there was no evidence that reestablishment of sagebrush in crested wheatgrass stands may be accelerated by higher intensities of use.

The advantages of crested wheatgrass for spring cattle grazing were shown by comparing daily weight gains from crested wheatgrass with nearby native range. Calves gained a pound more per day, and yearlings a half pound more, on crested wheatgrass grazed at the medium intensity compared with native range grazed at comparable intensity.

Weight gains of the cattle grazed on the seeded grass for about 1 month each spring generally averaged 2 pounds or more a day.

Daily gains of cows were inversely related to intensity of grazing. Daily gains of calves and yearlings were not affected by the different grazing intensities.

Rates of stocking were largely dependent on amounts of herbage produced. Because of large differences in herbage production from year to year, considerable flexibility in herd management is necessary to make the most effective use of crested wheatgrass for spring grazing. The safest practice appears to be to start spring grazing when leaves of the grass are 4 to 5 inches long, then graze for 4 to 6 weeks or until the stand is properly utilized.

For a month-long spring season under New Mexico conditions, the optimum intensity of grazing appears to be 65 to 70 percent utilization by weight of the herbage produced by the end of the grazing period. Under this degree of use, the seeded stand was maintained in a productive condition and gains on calves and yearlings were satisfactory. Cows were affected by grazing intensity, but, even so, they made ample gains. There is usually some additional summer and fall growth that helps maintain the vigor of plants heavily grazed in the spring.

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED

Grasses and Grasslike Plants

Agropyron desertorum (Fisch.) Schult.	crested wheatgrass [4]
A. smithii Rydb.	western wheatgrass
Bouteloua gracilis (H.B.K.) Lag.	blue grama
Carex foenea Willd.	silvertop sedge
Festuca arizonica Vasey	Arizona fescue
Koeleria cristata (L.) Pers.	Junegrass
Muhlenbergia montana (Nutt.) Hitchc.	mountain muhly
Poa pratensis L.	Kentucky bluegrass

Forbs

Hymenoxys richardsonii (Hook.) Cockerell	pingue

Trees and Shrubs

Artemisia arbuscula Nutt.	low sagebrush
A. cana Pursh	silver sagebrush
A. tridentata Nutt.	big sagebrush
Chrysothamnus greenei var. *filifolius* (Rydb.) Blake	Greenes rabbitbrush
C. nauseosus (Pall.) Britt.	rubber rabbitbrush
C. vaseyi (A. Gray) Greene	Vasey rabbitbrush
C. viscidiflorus var. *elegans* (Greene) Blake	Douglas rabbitbrush
Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed
Juniperus monosperma (Engelm.) Sarg.	one-seed juniper
J. scopulorum Sarg.	Rocky Mountain juniper
Pinus edulis Engelm.	pinyon
P. ponderosa Lawson	ponderosa pine
Quercus gambelii Nutt.	Gambel oak

[4] The USDA Committee on Plant Nomenclature, in a meeting on March 27, 1956, recommended that *Agropyron desertorum* (Fisch.) Schult. be designated as crested and *A. cristatum* (L.) Gaertn. as fairway wheatgrass.

LITERATURE CITED

Blaisdell, J. P.
1949. Competition between sagebrush seedlings and reseeded grasses. Ecology 30 : 512–519, illus.

Cook, C. Wayne, and Stoddart, L. A.
1953. The quandry of utilization and preference. Jour. Range Mangt. 6 : 329–335.

——— and Stoddart, L. A.
1961. Nutrient intake and livestock responses on seeded foothill ranges. Jour. Anim. Sci. 20 : 36–41, illus.

——— Stoddart, L. A., and Kinsinger, Floyd E.
1958. Responses of crested wheatgrass to various clipping treatments. Ecol. Monog. 28 : 237–272, illus.

Frischknecht, Neil C., and Plummer, A. Perry
1955. A comparison of seeded grasses under grazing and protection on a mountain brush burn. Jour. Range Mangt. 8 : 170–175, illus.

——— Harris, Lorin E., and Woodward, Harry K.
1953. Cattle gains and vegetal changes as influenced by grazing treatments on crested wheatgrass. Jour. Range Mangt. 6 : 151–158, illus.

Fuelleman, R. P., and Burlison, W. L.
1939. Pasture yields and consumption under grazing conditions. Amer. Soc. Agron. Jour. 31 : 399–412.

Heady, Harold F.
1957. The measurement and value of plant height in the study of herbaceous vegetation. Ecology 38 : 313–320, illus.

Hervey, D. F.
1958. Improving sagebrush ranges for grazing use—progress report of the Great Divide Experimental Range.* Colo. Agr. Expt. Sta. Gen. Series 688, 14 pp., illus.

Hickey, Wayne C., Jr.
1961. Growth form of crested wheatgrass as affected by site and grazing use. Ecology 42 : 173–176, illus.

Hurd, Richard M., and Kissinger, N. A.
1953. Estimating utilization of Idaho fescue (*Festuca idahoensis*) on cattle range by percent of plants grazed.* U.S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta., Sta. Paper 12, 5 pp., illus.

Johnson, W. M.
1959. Grazing intensity trials on seeded ranges in the ponderosa pine zone of Colorado. Jour. Range Mangt. 12 : 1–7, illus.

Knox, J. H., Benner, J. W., and Watkins, W. E.
1941. Seasonal calcium and phosphorus requirements of range cattle as shown by blood analyses. N. Mex. Agr. Expt. Sta. Bul. 282, 28 pp., illus.

Mattox, J. E.
1955. A study of percent of plants grazed method of utilization determination and its application.* Mont. Agr. Expt. Sta. Cir. 88, 140 pp., illus.

National Academy of Sciences, National Research Council.
1962. Range research: basic problems and techniques. NAC/NRC Pub. 890, 341 pp., illus.

Parker, K. W.
1951. A method for measuring trend in range condition on National Forest ranges.* U.S. Forest Serv., Washington, D.C., 26 pp., illus.

Pingrey, H. B., and Dortignac, E. J.
1959. Economic evaluation of seeding crested wheatgrass on northern New Mexico rangeland. N. Mex. Agri. Expt. Sta. Bul. 433, 80 pp., illus.

*Address requests for copies to the originating office.

Plummer, A. Perry, Hull, A. C., Jr., Stewart, George, and Robertson, Joseph H.
1955. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. U.S. Dept. Agr., Agr. Handb. 71, 73 pp., illus.
Reynolds, H. G., and Springfield, H. W.
1953. Reseeding southwestern rangelands with crested wheatgrass. U.S. Dept. Agr. Farmers' Bul. 2056, 20 pp., illus.
Roach, M. E.
1950. Estimating perennial grass utilization on semidesert cattle ranges by percentages of ungrazed plants. Jour. Range Mangt. 3: 182–185, illus.
Stoddart, Laurence A., and Smith, Arthur D.
1955. Range management. Ed. 2, 433 pp., illus. New York, Toronto (etc.).
Watkins, W. E.
1943. Composition of range grasses and browse at varying stages of maturity. N. Mex. Agr. Expt. Sta. Bul. 311, 43 pp., illus.
1955. Digestibility of range grasses and grass-legume mixtures. N. Mex. Agr. Expt. Sta. Bul. 400, 21 pp., illus.
Wilm, H. G., Costello, D. F., and Klipple, G. E.
1944. Estimating forage yield by the double-sampling method. Amer. Soc. Agron. Jour. 36: 194–203.
Woolfolk, E. J.
1951. Crested wheatgrass grazing values.* U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 91, 10 pp., illus.

*Address requests for copies to the originating office.

U.S. GOVERNMENT PRINTING OFFICE: 1963 O—685-283